

GEOSCIENTIST

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The Fellowship Magazine of the Geological Society of London

 @geoscientistmag

[MISSION:
JURASSIC]



JURASSIC GIANTS

Phil Manning reports on an
international project to
uncover a lost world

BONE WARS

Paul Johnson on an
infamous scientific rivalry

TUNE IN

A geological map
of The Archers

ENGAGE!

Support your Regional Group,
urges Catherine Kenny

Year of Life Collection

The evolution of life on Earth has been intrinsically linked to the planet's climatic and biogeochemical state for several billion years. From microbes living deep in the crust to Himalayan tardigrades, and from the search for life's origins to predicting the future climate, life has occupied, adapted to and shaped virtually every environment with impacts across the breadth of the geosciences. This collection, part of the Society's Year of Life 2020, aims to collate recent and seminal papers that cover the breadth of geoscience research into the impacts, or the effects of, life on Earth and beyond. Reconstructing ecosystems from the Archaean to the Anthropocene, mass extinctions to the actions of microbes, and from deep sea vents to astrobiology.



Collection Guest Editors

Heda Agić, University of California Santa Barbara, United States of America

William Foster, University College Dublin, Ireland

Sophie Nixon, University of Manchester, United Kingdom

Sean McMahon, University of Edinburgh, United Kingdom

Duncan Murdock, Oxford University Museum of Natural History, United Kingdom

View the collection at
www.lyellcollection.org/cc/year-of-life-collection

Find out more about the Year of Life
www.geolsoc.org.uk/life20

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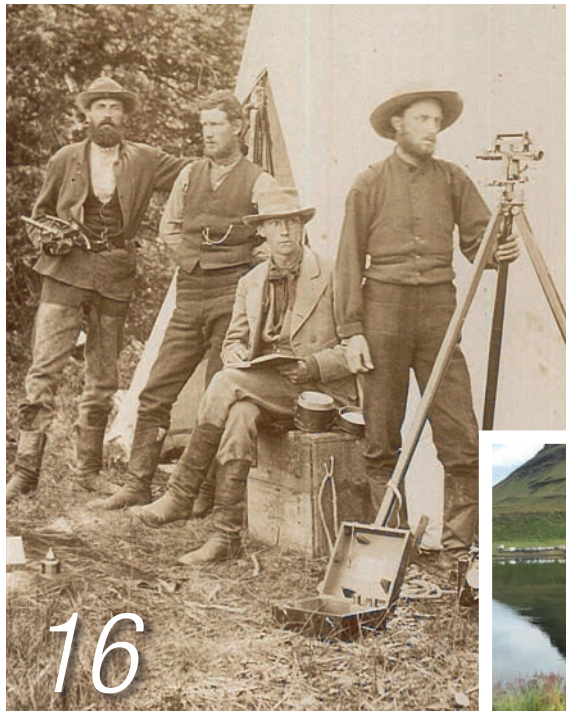
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Engineering on the precipice: the performance of mountain road rehabilitation in the Central Cordillera of the Philippines

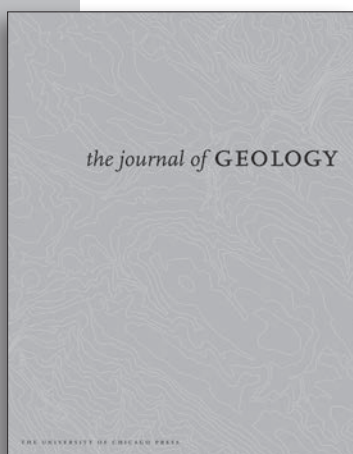
By G. J. Hearn and J. R. Hart

Parts of the Central Cordillera of Luzon are among the most challenging locations on Earth in which to build and maintain transport infrastructure, a situation perhaps most epitomized by the Halsema Highway. Since its original construction in the 1920s, the highway has undergone phased improvement and has become a socio-economic lifeline to the rural communities it serves. Unfortunately, in 1990, continuing road improvement works had to be abandoned owing to the outcome of a 7.8 Ms earthquake and the effects of subsequent typhoon damage. Earthquake reinstatement works were designed in 1998 and constructed between 2001 and 2006. The engineering geological challenge this posed was compounded by the effects of severe typhoon rains during the reconstruction period, requiring continual assessment of changing slope and drainage conditions. Since construction, the road has been affected by several new typhoons including, most notably, Typhoons Pepeng and Ompong in 2009 and 2018 respectively. Field inspections in 2010 and 2018, combined with the interpretation of satellite imagery available in Google Earth, have allowed the performance of the works implemented between 2001 and 2006 to be assessed and the outcome has been largely favourable. Very little of the recorded damage has occurred in the locations of earthquake reinstatement.



Instead, several new areas of slope failure and subsequent blockage and damage to the road have developed. Many of these areas can be explained with respect to their underlying engineering geology and geomorphology. However, there are just as many that owe their origin to the pattern of rainfall and runoff arising during the passage of individual and successive typhoons, modified significantly by drainage management practices in the road corridor, where engineering serviceability and land use practices sometimes have conflicting objectives.

➤ Read the full abstract and paper in the Lyell Collection <https://qjgeh.lyellcollection.org/content/early/2020/02/05/qjgeh2019-152>



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The Journal of Geology

EDITOR:
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“SO MUCH OF SCIENCE CAN BE DONE REMOTELY, IN LABS AND MODELS – FOSSIL HUNTERS STILL HAVE TO GET THEIR HANDS DIRTY”

FROM THE EDITOR'S DESK:

DINOMANIA

If there's one thing I could be sure of, during my ten plus years as a geological press officer, it was that dinosaur stories were a sure thing. Nothing else – not climate change, earthquakes, not even 'is the magnetic pole about to flip?' – came close. I didn't often get them – the meatier dinosaur papers were often snapped up by a university press office long before I could get my hands on them – but when I did, I knew a news outlet somewhere would cover them.

I even managed to spin the less obviously news worthy stories to accommodate them – on the publication of the Society's *Transactions of the Geological Society* (1811-1856) online, I went with 'Charles Darwin was crazy about dinosaurs', after spending a happy hour or so combing through the archives and searching for accessible names and topics. (It was, admittedly, a pity that the mobile version of one particular news site temporarily cut off the last two words of the headline.)

I don't know about Darwin, but for many of us, the obsession starts young. Anyone who's met a five year old will know that their encyclopedic knowledge of every species and its habits can be bafflingly accurate. This is, according to psychologists, an example of an 'intense interest' common among children – dinosaurs rank high, alongside trains, planes and cars. (I think the particular article I read may have been published before *Frozen* came out.)

Personally – and I know this will shock many – I wasn't that into dinosaurs as a child. Since working for the Geological Society, though, dinosaurs have become a sort of 'personal brand'

– I've been gifted more dinosaur themed paraphernalia than I can count (not complaining) and someone tweets me one of those videos of people in inflatable T-rex suits roughly once every 8 seconds (again, please do carry on.)

Apart from their obvious appeal – they're scary, but reassuringly extinct, despite what Spielberg would have us believe – perhaps it's the process of their discovery that fascinates us so. So much of science can be done remotely, in labs and models – fossil hunters still have to get their hands dirty. This month, Phil Manning takes us on a real life dinosaur hunt, to the fossil rich deposits of the Morrison Formation in Wyoming, where palaeontologists have been digging for more than a century.

That same appeal might explain why their discovery has caused so much rivalry and contention in the past – as well as the infamous 'bone wars' between Edward Drinker Cope and Othneil Charles Marsh (see pp 16-19) many other researchers fought over their dinosaur discoveries through history. Last year, the Society supported 'Dinomania' – a wonderful play by theatre company Kandinsky that recounts the bitter rivalry between Gideon Mantell and Richard Owen, and the discoveries that changed our understanding of Earth's history. Described by reviewers as 'intense', 'electric' and 'head-spinningly smart', the play's appeal went far beyond scientists gratified to see their subject on stage. Here was a tense, exhilarating drama that just so happened to be about science. Its success goes to show we're not just fascinated by dinosaurs, but by the very human stories of those who discover them.



SOCIETY NEWS

SOCIETY BUSINESS

COUNCIL REVIEW OF LIBRARY SERVICES

Long-term Fellows with a keen eye and good memory may recall a piece for the March 2010 issue of Geoscientist by past President Professor Peter Styles, announcing a review of Library services. Titled “From Gutenberg to Google”, the article set out the challenges our Library faced in spanning the print and digital worlds and catering for the developing needs (and preferences) of information consumers, and Council’s case for commissioning a review of how the Library acquires and manages its collections and services. Peter and colleagues reported to Council in November 2010 and many of their recommendations have subsequently been carried out.

It is no surprise that, ten years on, the information world in which we all work has continued to develop, offering new opportunities and making new demands on providers and users. The circumstances of the Society, too, have changed. While the Library and its services continue to be seen by many Fellows and visitors as a major benefit, and the sole benefit by some, its running costs continue to be high. Additionally, while the Library (journal, book and map collections for loan as well as precious and unique archives) occupies a large part of Burlington House, ongoing negotiations with the government over the Burlington House lease introduce some uncertainty about the location and size of the Society’s future home.

This new review will address these issues, with additional consideration of changing publisher practices and the Society’s relations with other Library service providers. The process will be chaired by myself and overseen by a working group comprising seven individuals with wide and varying experiences in Library development

and associated areas. Members of this group are:

Chair: Hazel Rymer (Professor of Environmental Volcanology at the Open University and former Pro-Vice Chancellor for Learning & Teaching Innovation; former Council member and Secretary, External Affairs)

Others (non-staff): Dave Quinn (representative of the Publications and Information Committee), Doug McClymont (Chair of the Library User Group), Graham Goffey (representative of the Finance and Planning Committee), Mark Thorley (Science & Technology Facilities Council; formerly NERC’s Head of Science Information), Gemma Wood (Manager, Special Projects at the Royal Society of Chemistry) Wayne Sime (Chief Executive of the Association of Learned and Professional Society Publishers; formerly Director of Library Services, Royal Society of Medicine)

Others (staff): Neal Marriott (Project Manager; formerly Director of Publishing)

The Working Group will be gathering and analysing wide ranging data in the coming months, consulting Fellows and seeking the views of both users and current non-users of our Library and information services. The aim will be to report to Council towards the end of the year.

I will be in touch with all Fellows a little later in the year with details on how you can contribute your views and ideas to the review.

Professor Hazel Rymer



Hazel Rymer in front of Kirkjufell, Snæfellsnes peninsula, West Iceland.

What your society is doing
at home and abroad



JOIN THE CAREER AND INDUSTRY DAY ADVISORY PANEL

Are you passionate about helping students and early career geoscientists? Excited about promoting your industry? Apply to join the newly launched Advisory Panel for the Geological Society's Career and Industry Days. Held in Edinburgh, Nottingham, and London, the events provide an opportunity for students to meet representatives from companies and academic programmes, and to hear from speakers from a range of industries.

We are looking to expand the range of industries and careers represented at these events, to ensure that students are aware of all the career and study options available to them. We are therefore creating an advisory board to help us connect with potential employers and career representatives. We are particularly looking for people to represent the following industries: geotechnical engineering, hydrology, contaminated land, mining and extractives, energy, government and NGOs, science communications and publishing, and alternative

careers such as finance or insurance. We are also looking for an academic representative for each region.

The commitment: We will host one virtual meeting of 1.5 to 2 hours once the panel has been established. We then expect panel members to identify and contact potential sponsors and exhibitors. GSL will then follow up with logistics and any other arrangements required. We will also ask our panel members to suggest potential speakers and topics for the oral session. Any reasonable expenses incurred will be reimbursed.

To apply: Please send a copy of your CV and a short cover letter detailing your interest in and ideas for the Career and Industry Days to alicia.newton@geolsoc.org.uk 15 April 2020

To find out more about our Careers and Industry Days, visit www.geolsoc.org.uk/careersday



NOTIFICATION OF OFFICERS 2020/2021

At the Annual General Meeting on 4 June 2020 Fellows will be asked to elect the following members of Council as Officers for 2020/2021:

President

Dr Michael Daly

Vice-Presidents

Mr John Booth
Mr Nicholas Reynolds
Miss Jessica Smith

Secretaries

Prof James Griffiths
Prof Robin Strachan
Dr Alexander Whittaker

Secretary, Foreign & External Affairs

Dr Joel Gill

Treasurer

Mr Graham Goffey

PRESIDENT'S DAY 2020

The Society announced the winners of its medals and funds for 2020 in the March edition:

Barbara Romanowicz (Wollaston Medal); Rachel Wood (Lyell Medal); Katharine Cashman (Murchison Medal); Alastair Ruffell (William Smith Medal); Kristján Saemundsson (Prestwich Medal); Alastair Robertson (Dewey Medal); Sandra Herbert (Sue Tyler Friedman Medal); Richard Davies (Coke Medal); Lisa McNeill (Coke Medal); Bill Gaskarth (Distinguished Service Award); Bridget Wade (Biggsby Medal); Andrew Newton (Wollaston Fund); Thomas Hearing (Lyell Fund); Alexander Dunhill (Murchison Fund); Emma Jude (William Smith Fund).

The President's Awards for 2020 are awarded to Dr Tim Gregory of University of Bristol/British Geological Survey and Dr Thomas Phillips of Durham University.

The Awards will be presented at President's Day, on **4 June 2020**. On that day there will be research talks by the senior medallists: Barbara Romanowicz (Institut de Physique du Globe de Paris); Rachel Wood (University of Edinburgh); Katharine Cashman (University of Bristol); Alastair Ruffell (Queens University Belfast).

All Fellows are welcome to attend the events of President's Day, though lunch with the Award winners will incur a charge. Full details of charges and instructions for registration will be published in the May issue and online.

POLICY UPDATE

WHAT CONSTITUTES RESPONSIBLE INVESTING IN NATURAL RESOURCES?

In October 2019, interdisciplinary delegates from mining, oil and gas companies, investors and other financial institutions, consultancies, NGOs and universities explored what constitutes responsible investment in the extractive sector. During a two-day workshop at the Society, they considered how it might be verified and quantified, identified drivers and barriers to achieving it, and proposed actions to support and stimulate its implementation. Read our policy briefing note at www.geolsoc.org.uk/gsl-responsible-investing to find out more.



CORONAVIRUS UPDATE

Due to the rapidly evolving government advice around travel and public gatherings, the Geological Society and our regional and specialist groups have postponed many lectures and conferences in April and early May. Please check our events page (<https://www.geolsoc.org.uk/events>) for up-to-date information. Please also check before travelling to Burlington House, as we may need to close to the public on short notice.



Geology Student Enrolment Summit

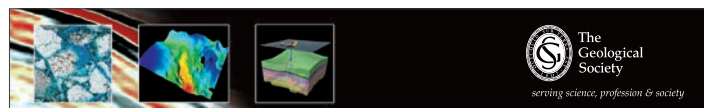
- **Wednesday 24 June 2020**
- **The Geological Society, London**

The Geological Society of London will bring together key stakeholders and representatives from the education, higher education, employer and non-profit sectors at Burlington House for a Geology Student Enrolment Summit.

This day-long event will centre on identifying and understanding the reasons behind a declining number of students enrolling on geoscience degrees in the United Kingdom, and how we as a community can address this.

If you wish to take part as an individual or as a representative for your organisation, please email us at diversity@geolsoc.org.uk and explain (in no more than 250 words) how you can contribute.

Visit our event page to find out more:
www.geolsoc.org.uk/enrolmentsummit



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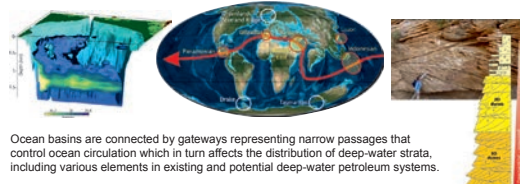
Call for Abstracts – Deadline: 30 June 2020

Oceanic Gateways: Modern and Ancient Analogues and their Conceptual and Economic Implications 28-30 September 2020

The Geological Society, Burlington House, Piccadilly, London

Convenors:

- F. Javier Hernández-Molina, RHUL, UK
- Rachel Flecker, Bristol University, UK
- Anna Wählin, Univ. Gothenburg, Sweden
- Domenico Chiarella, ENI, Italy
- Eleanor Stirling, BP, UK
- Karyna Rodriguez Sanchez, UK
- Francois Raison, TOTAL, France
- Giancarlo Davoli, ENI, Italy
- Juan J. Fedele, ExxonMobil
- Lauren Mayhew, Cairn Energy



Ocean basins are connected by gateways representing narrow passages that control ocean circulation which in turn affects the distribution of deep-water strata, including various elements in existing and potential deep-water petroleum systems.

In the geological past, the onset and closure of palaeogateways has influenced the global ocean circulation, climate, distribution of biota, evolution/extinction events, evolution of basin evolution, sedimentary processes and hydrocarbon source rock and reservoir distribution.

This three-day conference aims to bring together diverse experts working on modern and ancient gateways in order to improve our knowledge, models, and predictive power. Sessions will include the following themes:

- Oceanographic / palaeoceanographic processes
- Tectonic controls on gateway geometry
- Sedimentary processes and deposits within and around gateways
- Data integration and multidisciplinary analysis
- Implications of gateways and contourite deposits for hydrocarbon exploration.

We invite oceanographers, palaeoceanographers, geomorphologists, sedimentologists and marine geologists, as well as petroleum geologists and researchers working in numerical modelling and plate tectonic reconstructions, to join the conference.

Call for Abstracts:

Please submit talk or poster abstracts to sarah.woodcock@geolsoc.org.uk by 30th June 2020.

For further information please contact:

Sarah Woodcock, The Geological Society, Burlington House, Piccadilly, London W1J 0BG. Tel: +44 (0)20 7434 9944
Web: <https://www.geolsoc.org.uk/pg-oceanic-gateways-2020>

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#PGOceanicGateways20

Engage!

In the fight to encourage more students to take up geology, Regional Groups are key, says **Catherine Kenny**



The bleak future of the study of geology has been well documented, with geoscience departments globally reporting a decline in student enrolment (see *Geoscientist* 29 (8) September 2019 for more). There are plenty of initiatives underway to turn things around, but it can feel hard to see how one geologist can make a difference. As a Fellow of the Geological Society – and particularly as a member of your Regional Group – there are lots of ways you can help.

The North West Regional Group

The committee of the North West Regional Group spend a lot of time trying to engage as many different people as possible with geology. We have a mailing list of 904 people and an absolutely massive area to cover, stretching south to north from Staffordshire to Cumbria and west to east from North Wales to the Pennines. We try to move our lectures around the region, and select subject matter from as many different areas of geology as we can. And if lectures are not your thing, maybe you can try a field trip: last year, we organised five trips all over the region, at weekends and evenings.

But it's the engagement of the younger generation that is the real issue. Geology is all but gone from the school curriculum, hanging by its teeth in year 3 of primary school. Children spend less and less time outside; playing in the foundation trenches of your local building site or mucking about in your local quarry like we used to in the 70s is now (rightly) Frowned Upon.

Children are just not encountering the natural environment as much anymore. And if they don't know about it, they can't get interested in it, they don't think about studying it, they can't recognise it as important, and, worse, they won't protect it as it becomes increasingly threatened by modern

life. The study of geology is more important than ever, as the general populace slowly comes to the realisation that we are playing real-life Minecraft on Survival Mode, with the monsters switched on.

A many-pronged approach

The North West Regional Group is trying a many-pronged approach. Last year, at the pre-school upwards level, we organised a child-friendly lecture and trip around the Manchester Museum on the theme of pliosaurs (see the NWRG Autumn 2019 Newsletter <https://www.geolsoc.org.uk/Groups-and-Networks/Regional-Groups/North-West/Newsletters>). For A level students, there is the Schools Challenge (<https://www.geolsoc.org.uk/geochallenge>). In March 2019 we ran a careers event for degree course students, hosted by the University of Manchester. Speakers from local companies described their own career pathways in geoscience, and also had a stall to chat to students and hand out information. We ran a "speed networking" event as part of this, where students could talk directly in small groups to volunteer graduates at early stages in their careers.

Students from all over the region attended and obtained a useful insight into the range of careers available and the skills required.

All these things take time, and a lot of volunteers - as speakers, competition judges, networkers and organisers. We are truly grateful to all those that took part - we all need to get involved to sway the current crisis. If you can help, contact your regional group. In the words of Jean-Luc Picard: Make It So.

Catherine Kenny is Secretary of the North West Regional Group, a Consultant Geologist and School Science Technician, with a husband, two children, a house in various states of disrepair and six cats. (Don't ask about the six cats.)



SOAPBOX CALLING!

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

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

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

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

“GEOLOGY IS ALL BUT GONE FROM THE SCHOOL CURRICULUM, HANGING BY ITS TEETH IN YEAR 3 OF PRIMARY SCHOOL”

CATHERINE KENNY



EXCAVATING JURASSIC GIANTS

Phil Manning on an international palaeontological project to reconstruct a lost world

"Kelsey"



Fig 1: Dinosphere at The Children's Museum of Indianapolis

The field of palaeontology has rapidly expanded in the past few years through the application of new technology and techniques, but its roots are still firmly anchored in the Earth's past. The hindsight that the fossil record provides can help us better understand today's biosphere – it's always worth remembering that the ebb and flow of life has always been steered by the processes governing our dynamic Earth. Fossils can provide powerful insight to the past, but also to the very systems that impact our present and future planet.

The exploration and excavation of fossils still provides the critical fuel that keeps the fires of this subject burning. As each field season approaches, the palaeontological 'itchy feet' twitch. Collecting your first fossil of the season is a warm and familiar feeling that spreads through the body... but hopefully not a function of heat stroke.

The Jurassic Mile

Approximately five years ago, the University of Manchester (UoM) Interdisciplinary Centre for Ancient Life (ICAL) was approached by a team of scientists from The Children's Museum of Indianapolis (TCMI), to work on an exciting new discovery - a dinosaur-bearing site in the Morrison Formation of Wyoming (USA).

The fossil remains of Cretaceous dinosaurs already populate TCMI's *Dinosphere* exhibit and have captivated more than 15 million visitors over the last ten years, inspiring a new generation of explorers and scientists. The new site offered the opportunity to excavate and study an area rich in fossil remains that can then be translated into a new TCMI 'Jurassic' exhibition gallery in the coming years.

Soon nicknamed 'The Jurassic Mile' by TCMI President Dr. Jeffrey Patchen, the site comprises a square mile (640 acres) of prime Wyoming Jurassic in the Bighorn Basin, close to the border with Montana (Fig 8.). Whilst vast, it offers a rare opportunity to plan and execute an excavation, and is now on a 20 year

► lease with TCM. The scale of the project has brought together scientists from across the globe, and involved collaboration with the Naturalis Biodiversity Center (NBC) in the Netherlands, London’s Natural History Museum (NHM) and the Stanford Synchrotron Radiation Lightsource.

The Jurassic Project is already utilising cutting-edge science, from synchrotron-based imaging of fossils to using high-performance computers at the UoM to help resurrect the locomotor ability of Jurassic dinosaurs through stress-constrained multi-body dynamics. The project has

become a productive partnership between museums and universities that has added momentum to the process of unearthing lost worlds and forgotten lives.

Bone Wars

Dinosaurs have been excavated from the Morrison Formation for over 100 years; this slice of geological time has long been associated with remains of some of the largest vertebrates to have walked the Earth. The infamous ‘Bone Wars’ between Yale University’s Othniel Marsh and the Philadelphia Academy of Natural Science’s

Edward Drinker Cope helped to drive the field forward at a remarkable pace- sadly, a precursor to similar pointless feuds that continue in this and many other fields of science.

The fossiliferous sediments of Como Bluff, near Medicine Bow, Wyoming, is where many of Marsh and Cope’s Bone Wars took place. The large anticline ridge contains three fossil-rich Late Jurassic Formations (including the Morrison) that continue to offer new species to palaeontology. It is a historical quirk that as the Battle of Little Bighorn was playing out, a dinosaurian drama was co-occurring between the Yale and Philadelphia palaeontologists, a mere stone’s throw away.

Over the past decade the Jurassic Mile had been lightly ‘picked-over’ by a handful of commercial collectors, but they have thankfully not made much of a dent on the locality. As stories of fossil bones from the area filtered between ranchers, collectors, and eventually museum bone-hunters in Indianapolis, the project slowly evolved. Once the site had been assessed by the TCMi and UoM team, it was clear that a 20-year lease on the square mile would yield many Jurassic fossils for the proposed expansion of TCMi’s already successful *Dinosphere* exhibit. The lease was negotiated by TCMi and the hard work of what we now know as “Mission Jurassic” began in December 2016.

I recall this timing well; our team had to fly to Wyoming to review the site and

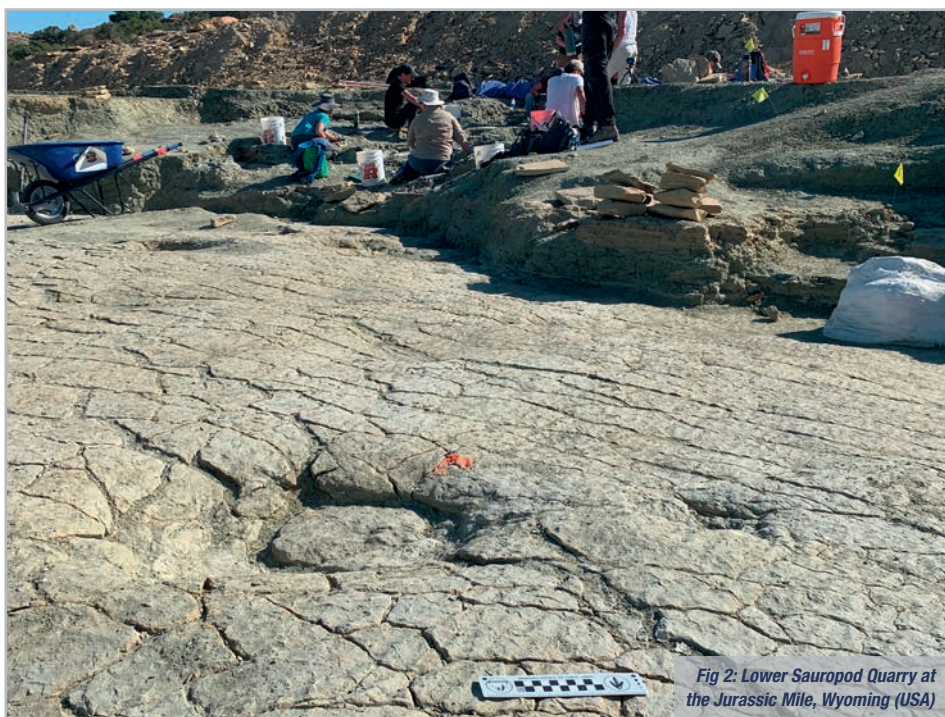


Fig 2: Lower Sauropod Quarry at the Jurassic Mile, Wyoming (USA)



Fig 3: Upper Sauropod Quarry at the Jurassic Mile in December 2016

make sure that any exposed bones were suitably covered up for the Wyoming winter. Unfortunately for us, the winter arrived early and temperatures of -30°C and heavy snow hampered our 'winterfying' of the site. This was without any doubt some of the coldest fieldwork our team has ever undertaken.

The Morrison Formation

The sedimentary rocks of the Jurassic Mile represent several millions of years in the geological history of Wyoming. The oldest rocks exposed that underpin the site were laid down in the Sundance Sea, a body of water that slowly retreated northwest at the end of the Jurassic in North America, now represented by the rocks of the ~160 million-year-old Sundance Formation. These marine sediments contain a diverse fauna of invertebrate and vertebrate fossils that typify the Late Jurassic.

The TCM and UoM team have already discovered many fossils within the marine succession here, including partial skeletons of the marine reptile *Baptanodon* (an ophthalmosaurid ichthyosaur). However, it was not the Jurassic marine reptiles that initially drew the team to the site, but the abundance of dinosaur bones that were in the overlying geologically

younger (approximately 150 million years old) rocks of the Morrison Formation, made so famous by Marsh and Cope.

The overlying sediments making up this terrestrial succession were laid down on a vast coastal floodplain that initially edged onto the retreating Sundance seaway, but eventually was infilled by the sediments of large meandering river systems. The sedimentary forms replay the depositional environments from the evidence preserved in their structure, composition and appearance. Over-bank muds, channel-sands, sandbars and finely bedded pond/lake deposits make up this exposure of the Morrison Formation, dominated by a repeated succession of sandstones and mudstones so typical of this Formation.

As with many such depositional systems, they were occasionally subject to environmental perturbations; sometimes slow (drought), but other times more sudden (flood). These events left their sedimentological signature written in stone, sometimes with the additional ingredient of life that had once flourished upon, alongside and/or within the said sediments. The frustration with terrestrial organisms is that they are rarely found in the precise environment in which they were adapted to live. Life has the habit of being thrown together as a phylogenetic fossil soup that can be hard to disentangle and decipher.

A complex ecosystem

Work at the Jurassic Mile has exposed an extraordinary number of dinosaur remains (as my post-fieldwork aches and pains attest), but unusually the site also preserves stunning dinosaur trackways and a diverse array of fossil plants that will help build a more complete picture of the ecosystem—or as complete as is possible for palaeontologists. An oft repeated 'general rule' tells us that it's rare to find a cooccurrence of associated bones, plants and trackways at the same location. One thing I have learnt in 40 years collecting fossils: if there is a 'general rule' on what 'should' be preserved, you should simply look a little harder.

The first evidence we found of tracks on the Jurassic Mile were from the spoil heaps dug by the prior 'visitors' to the site who had been working in what is now our lower Morrison Formation quarry. The huge (up to 1 metre in length) foot casts of sauropod dinosaurs had been totally overlooked, possibly due to their sheer size. A few tell-tale deformation features, not even complete tracks, were enough to alert us to their presence, albeit not in-situ. It was not long before we identified multiple track-bearing horizons throughout the succession.

It was good to discover something that had been hiding in plain sight; something ►



Fig 4: Prof. Phil Manning with sauropod femur, Jurassic Mile, Wyoming



Fig 5: Dinosaur trackways revealed in-situ at Jurassic Mile, Wyoming



Fig 6: A Western diamondback rattlesnake at the Jurassic Mile site

► so obvious that had been overlooked for so long. The track horizons were also visible in pond/lake deposits and are often intimately associated with bone-rich layers. The dinosaur trackways were associated with the bones of sauropods (such as the famous diplodocid and macronarian sauropods) and theropod (predators such as Allosaurus) dinosaurs, which the track morphologies also reflect. These traces of movement provide powerful evidence from which the team can better understand the locomotion and ecology of these long extinct animals.

‘If you don’t like the weather, just wait five minutes’

The 2019 excavation turned out to be one of the longest field seasons in my whole career. We got to site in late May, while snow was still on the ground, and were in the field until August 31st. The Jurassic Mile dig was again led by the TCMi and UoM field crews, but in 2019 we were also lucky to host teams from the NBC and London’s NHM, whose staff and equipment joined the dig to explore the Jurassic Mile, contributing valuable time and equipment.

We experienced almost every type of weather you could imagine for this remote part of northern Wyoming, from snow and freezing conditions to soaring

temperatures in the low 40°s C and some of the most memorable thunderstorms I have ever suffered in the field. Some of the team had not experienced the extreme weather that Wyoming has to offer before; they soon learnt that ‘bad weather’ in this state was something to be respectful of. While Montana is ‘Big Sky’ country, I would argue Wyoming wins the ‘Big Weather’ award - as the rancher from whom the land is leased commented, *“If you don’t like the weather, just wait five minutes”*.

Working in the field with such changeable conditions brings its own unique set of challenges. Not least of these is figuring out an exit strategy, should a sudden storm wash out the only road from the site. Thankfully, years of forecasting the impact of weather fronts in the field combined with a careful watch of local weather patterns had our team in danger of being stuck only once...very nearly!

Getting used to the local wildlife is also a challenge - last time I looked, bears, black widow spiders, rattle snakes and scorpions weren’t thick on the ground in Manchester. Many members of the team had to recalibrate their hazard awareness to account for the exotic and potentially dangerous wildlife all around us. I have never been a great fan of venomous snakes, and the venomous arthropod

community was also well-represented. A big surprise to our team, especially when it was snowing, was the number of scorpions we came across as we opened up the Jurassic Mile quarries. If you believe the guide books, these beasts are rare - they are not, and should be treated with respect. Listening to advice on the presence or absence of any animals on a site, from extinct to extant, should be done with some caution.

Depositional environments

The diversity and abundance of the extinct life found at the Jurassic Mile might well stem from the multitude of depositional environments. The taphonomic ‘mill’ that regularly alters the fossil record has been kind to creatures discovered at the Wyoming site. Taphonomy (*taphos* ‘burial’ *nomos* ‘laws’) is the study of the processes that impact how life enters the fossil record through death, burial and fossilization. Most palaeontological studies, particularly anatomical and palaeoecological ones, depend on an ability to strip away the taphonomic overprint. This brings us to another key facet of the dinosaur bones at the Jurassic Mile - many of them are uncrushed and preserved in glorious 3D.

The burial of bones can be cruel to the survival of fine skeletal structures; often

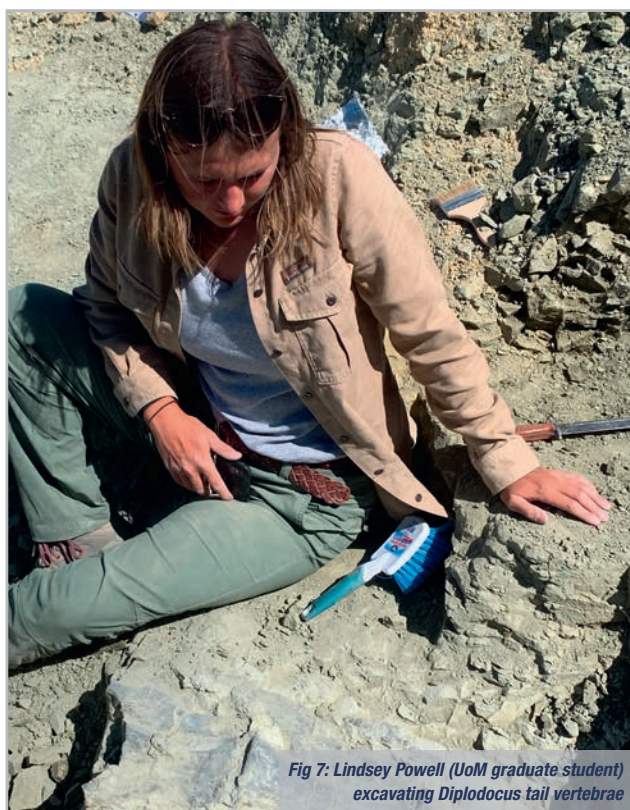


Fig 7: Lindsey Powell (UoM graduate student) excavating *Diplodocus* tail vertebrae

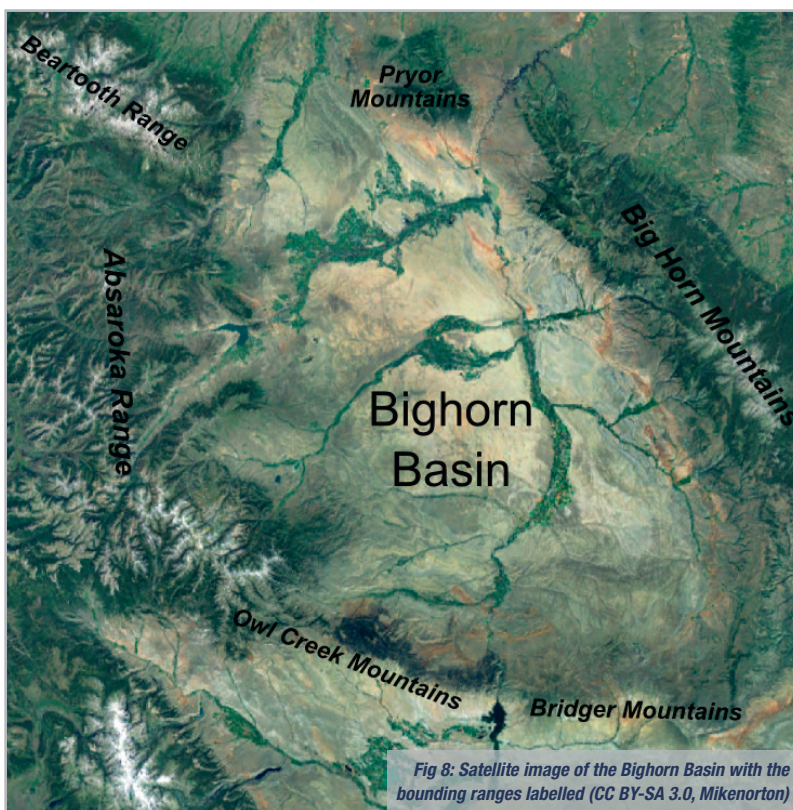


Fig 8: Satellite image of the Bighorn Basin with the bounding ranges labelled (CC BY-SA 3.0, Mikenorton)

key anatomical information is lost over geological time. The bones at the new site are preserved extraordinarily well, exhibiting little to no crushing with very delicate (sub-millimetre) bone laminae surviving in-situ - in some cases for the first time in known species. The exceptionally preserved fossil plants are possibly the icing on the geological cake, offering a hitherto unseen association of plants with animals in quite specific environments (lake, overbank, pond and channel systems). The combination of all these factors makes the Jurassic Mile a perfect place to be studying this point in geological time. If you wanted to freeze-frame a moment in the Jurassic to record life and the environments in which it thrived, it would be here.

While the southern Morrison sites of Arizona, New Mexico, Utah, Colorado and southern Wyoming are of both historical and scientific importance, their relationship with the Bighorn Basin sites of northern Wyoming, including our own, is not clear. The few studies that have taken place have yielded dinosaurs that do not seem to match the shape, form, and distribution seen in the Southern Morrison with what we've found in the North. Many scientists now suggest that they are not just separated in space (spatially), but also in time (temporally). The gap might only be a

few millions of years, but some suggest that the northern fauna might be separated by as much as 10 million years from the southern populations.

If this separation is as long as some suspect, it is likely that many of the dinosaurs being discovered in the Bighorn Basin could represent new species. Some have gone so far as to suggest that the northern population might have been isolated from other geographic areas, which also caused distinct adaptations specific to this palaeogeographic area—this leading to speciation different from elsewhere in the Morrison Formation. One of the Mission Jurassic goals is to resolve the timing of the deposition of this location/package of time and describe the species found within this extraordinary site.

The future

We started with a 20-year lease and now have 16 years remaining to explore, excavate and undertake the science that will hopefully help tell a fuller story of the Jurassic. The team have already invested four years exploring, mapping, and excavating the site. The next two to three will focus on placing two vast sauropod dinosaurs on display at TCMI; our current primary focus and mission. However, working with the project leads at TCMI and partners at the NBC, we hope to help

further develop the Jurassic Mile's research potential in the coming years. This will no doubt involve the excavation of additional dinosaurs and hopefully the discovery of much that is new to science.

Mission Jurassic is a splendid example of international collaboration that will help to explore and hopefully resolve some of the mysteries that still exist in the Jurassic. This is also a great example of how a world-class museum (TCMI is the largest children's museum in the world!) can work with European research partners to deliver a multi-million-dollar project that benefits countless communities, both public and scientific.

Sixteen years from now, we will know so much more about a point in Earth's history when there were no polar ice caps, oxygen levels were higher, life was thriving (and very big!), and the world was rapidly changing. We live in such a changing world today and it is through studying these lost worlds and forgotten lives that we might begin to build a sustainable bridge to our own future on this fragile Earth.

by Professor Phillip L. Manning

- Chair of Natural History, Interdisciplinary Centre for Ancient Life, Department of Earth and Environmental Sciences, University of Manchester, Manchester UK.
- Scientist in Residence, The Children's Museum of Indianapolis, Indianapolis, Indiana, USA

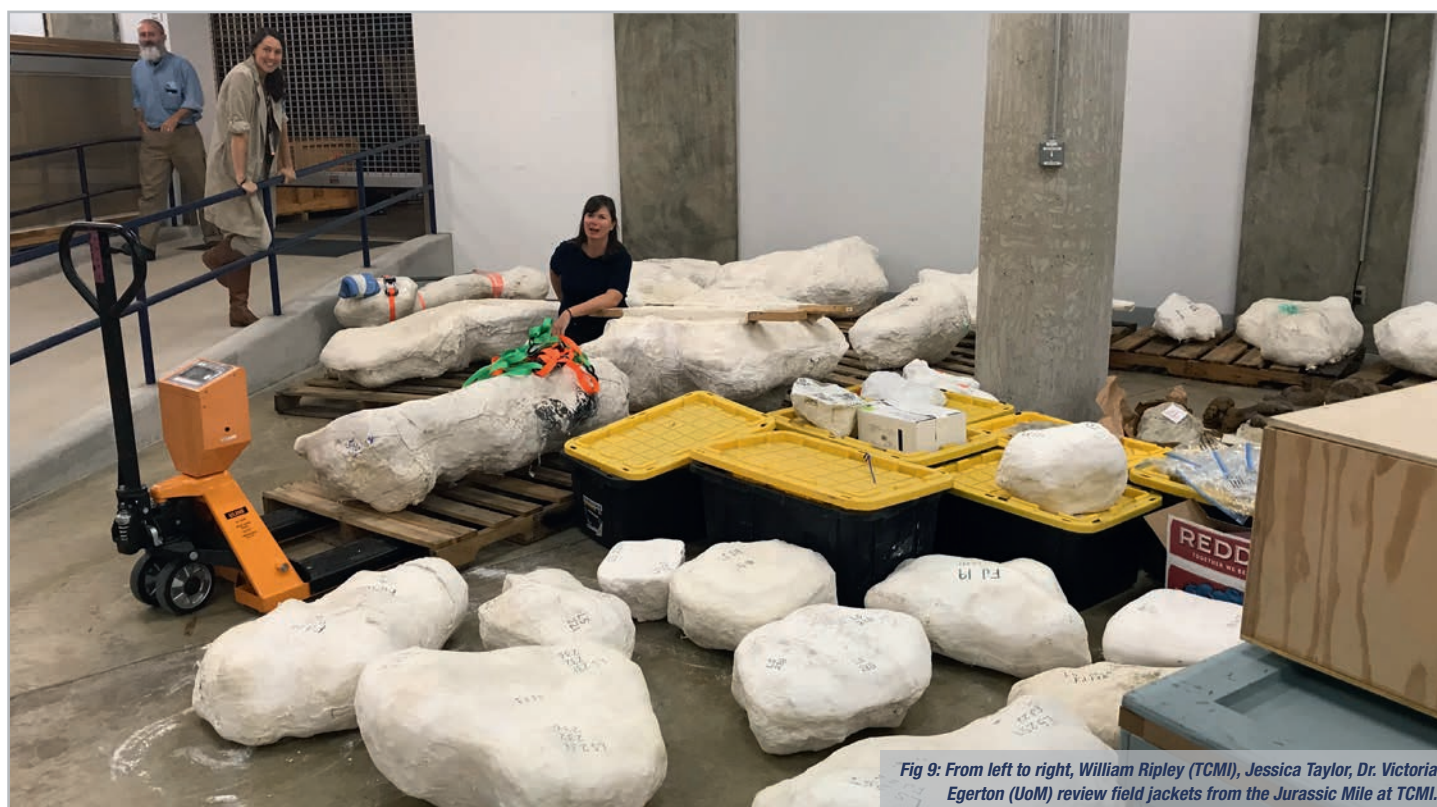


Fig 9: From left to right, William Ripley (TCMI), Jessica Taylor, Dr. Victoria Egerton (UoM) review field jackets from the Jurassic Mile at TCMI.



DINOSAUR RUSTLING IN THE OLD WEST

Paul Johnson recounts the tale of the notorious 'Bone Wars'

1876

was a momentous year for the expanding United States of America. Jesse James and his gang attempted their catastrophic bank robbery in Northfield, Minnesota, resulting in the deaths of all but James himself and one other. The first transcontinental express railroad trip was made from New York to San Francisco. Wild Bill Hickok was shot in the back playing poker.

That year also saw the Battle of Little Bighorn and Custer's Last Stand, themselves part of the great Sioux Wars that ranged across the Dakota Territory – the huge chunk of land in the American plains that the United States coveted but did not own. With the discovery of gold in the Black Hills prospectors moved into the area, and the US Government did very little to stop them. They trespassed upon land that the Lakota tribes considered sacred and even built the town of Deadwood to facilitate their adventuresome ways. For the space of a year in vast tracts of the West from Colorado north through Nebraska and Wyoming to Montana and Dakota, war raged between the indigenous Americans and the interlopers from the East.

It was all getting a bit too hot for some, most notably two men who'd been prospecting for the best part of a decade in the area and were already squabbling over their finds. For their workers and colleagues, the risk was too great; they retreated to places of greater safety. All geologists Othniel Charles Marsh (1831-1899) and Edward Drinker Cope (1840-1897) could do, for a year at least, was to head back East to catalogue the vast piles of fossilised bones they had excavated, and produce their scientific papers.

Parallel careers

Othniel Marsh was the nephew of George Peabody, founder of J.P.Morgan

and noted philanthropist. His uncle's funds helped him through Yale University where he studied anatomy, mineralogy and geology, and on to Europe, to continue his studies in Berlin.

Edward Cope came from an orthodox Quaker family and had a father who doted on him. He pushed hard for the university education he received, finding himself re-cataloguing the herpetological collection at the Academy of Natural Sciences. Even at this young undergraduate age, he began publishing papers on the classification of various reptiles and amphibians. When the Civil War began, he too found himself travelling to Berlin. It was here that the paths of Marsh and Cope first crossed.

Initially they got on well, sharing dinners, touring the city and sharing their mutual love of palaeontology. Once they returned to their researches, they took turns naming new species after one another. But something clearly rankled both men about the other. Maybe it was the wealth and opportunity that Marsh possessed; perhaps it was Cope's extensive record of publications at an early age. Whatever the reason, a brief period of amity was replaced by rumblings of hostility.

The rivalry intensifies

Both men returned to the US in the 1870s, drawn by the promise of large fossil finds. By now, their relationship had become tense, with the two publically attacking each other in papers and publications. Following a visit to a promising site in New Jersey, Marsh had secretly bribed pit operators to send news of any future fossil finds to him. Meanwhile, Cope found employment with Ferdinand Hayden's Survey and took to prospecting for bones in areas that Marsh had previously considered his own territory. The rivalry grew - as did the number of finds emerging from the American West.

They argued in print about ►

USGS surveyors, c. 1870s. From the album *Photographs of the principal points of interest in Colorado, Wyoming, Utah, Idaho & Montana* (Geological Society of London Archives)



Figs 1-3: Monochrome lithographs issued by the United States Geological Survey, [1878-1899] depicting the bones of sauropods and brontothers. Lithographed by E Crisand, New Haven, after drawings by Frederick Berger, under the supervision of Othniel Charles Marsh, [1878-1899].

► classification. They argued about naming. Most of Marsh’s names held, as did his classifications. The speed with which finds could be excavated, shipped, examined and described became critical; both men knew the other had made similar finds in similar locations and they could not risk being second in print. Both were working in territories where the law was weak and tempers fiery among those prospecting for riches. With the discovery of gold in the Black Hills, mines started opening - and where there were mines, there was the prospect of bones being found.

Dakota was dangerous territory. Marsh headed there with a large group, protected by soldiers. Cope found employment with the Army Corps of Engineers, but this limited him to finds where the Army was surveying. Marsh, meanwhile, could not only dig where he chose, but also championed the cause of the Lakota and gained the support of Chief Red Cloud, interceding where he could between the tribes and the army.

It was not to be successful. The pressure of speculators led to the upheaval of 1876, and Marsh and Cope headed back East. Marsh would never to return West again. Their grudge would play out in elegant society, not in the streets of a Western settlement.

Como Bluff

1876 was also a turning point for their discoveries. Colorado joined the Union that year and shortly thereafter Marsh and Cope received letters that something enormous was lurking beneath Como Bluff in that state. Marsh immediately paid his correspondent \$100 to keep quiet; an expense that evidently had no effect, as Cope was informed by others.

Word was spreading that these two men would pay handsomely for old bones. Two construction workers on the Transcontinental railroad knew the area well and played Marsh off against Cope, raising the price of the information still further – but this was money well spent. Soon whole wagons full of bones were making their way to

Yale – and these weren’t any old bones. They were the first specimens of *Diplodocus*, *Allosaurus* and *Stegosaurus* – hastily reconstructed, named and described by Marsh before the end of 1877. This was the motherlode of dinosaur fossils and Cope was not to be excluded. He instructed his men to spy and “rustle” Marsh’s dinosaurs out from under his nose.

Marsh may have had more money than Cope, but his payments were not always as speedy as his promises; those he had employed defected to the other side. Some employees grew fed up with the whole game, whilst others destroyed those bones they were unable to transport to prevent them falling into the hands of the other side. Paper after paper appeared in academic journals, some more hastily written than others. As the battle wore on, one of Marsh’s favourite tactics became to point out every single error he could find in Cope’s work and the speed both were working at led to many errors – most famously, Cope’s botched reconstruction of the plesiosaur *Elasmosaurus*.

Exposure

As the 1880s wore on, the skulduggery, shenanigans and outright criminality continued, and Marsh’s advantages of status and finance paid off as he drew ahead in the race to publish and

“ BOTH WERE WORKING IN TERRITORIES WHERE THE LAW WAS WEAK AND TEMPERS FIERY AMONG THOSE PROSPECTING FOR RICHES. WITH THE DISCOVERY OF GOLD IN THE BLACK HILLS, MINES STARTED OPENING - AND WHERE THERE WERE MINES, THERE WAS THE PROSPECT OF BONES BEING FOUND ”

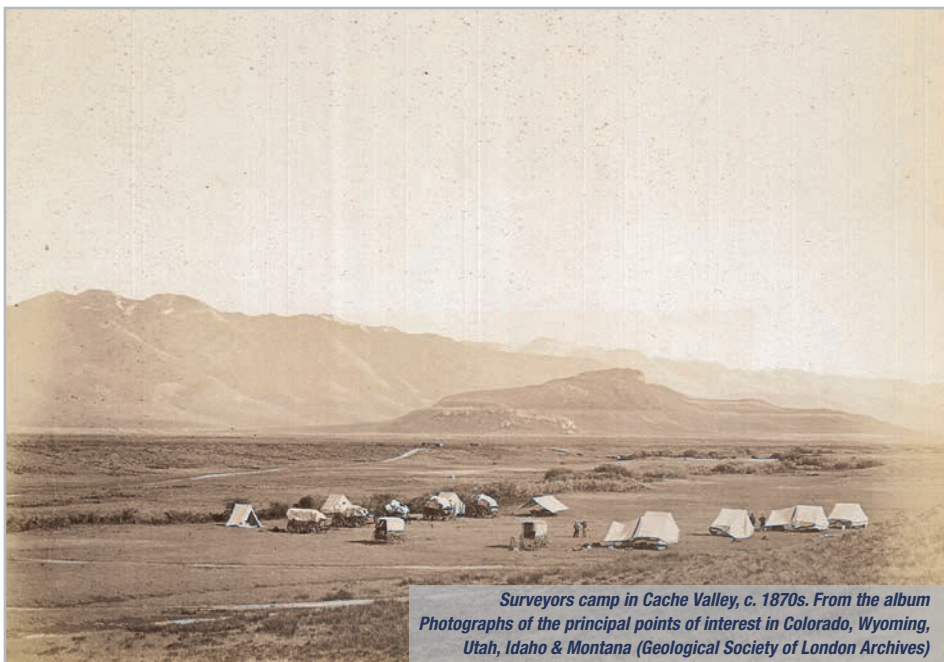
collect. Cope would not let go, and saw his chance when his mentor, Ferdinand Hayden, retired from the fledgling United States Geological Survey, and Marsh became a director. Cope went public, listing all of Marsh's misdemeanours and taking testimony from employees regarding his behaviour. Cope had these accounts and records published by the decidedly non-academic journal the New York Herald. Palaeontology, or at least its practice, was suddenly front-page news, and the world was aghast.

Marsh and Cope's personal grudge ended, not at high noon on a dusty main street, but in the universities of the eastern US. Marsh lost his position at the USGS. Cope began to suffer

increasingly bad health. The war between them ran out of steam, leaving two angry and shattered men and a wide variety of discoveries the like of which the world had never seen before.

Their lifelong feud had a strange coda. Before his death in 1897, Cope challenged Marsh to leave his brain to science so that those of both men might be weighed and measured, to ascertain once and for all which had been the biggest. Unsurprisingly, Marsh declined, but Cope's skull reportedly remains in the collection of the University of Pennsylvania, along with many of his finds.

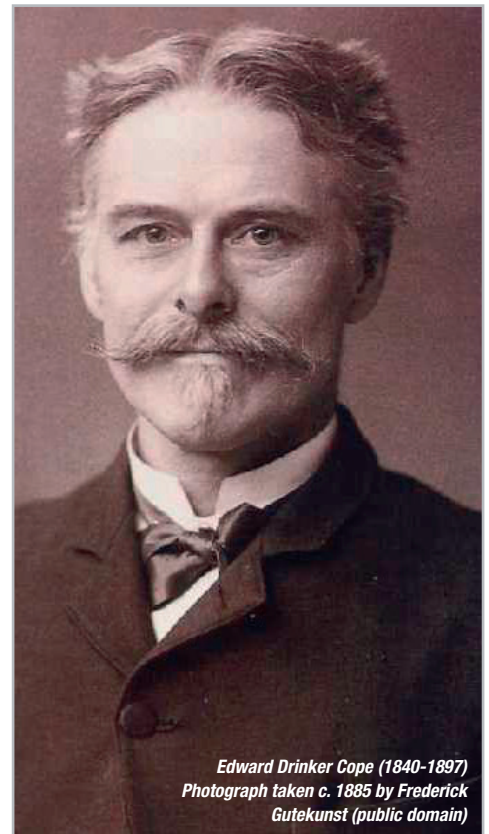
Paul Johnson is the Geological Society's Map Librarian



Surveyors camp in Cache Valley, c. 1870s. From the album Photographs of the principal points of interest in Colorado, Wyoming, Utah, Idaho & Montana (Geological Society of London Archives)



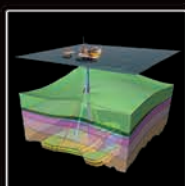
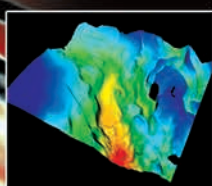
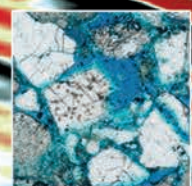
Gold mining in 1870s Blackhills, c. 1870s. From the album Photographs of the principal points of interest in Colorado, Wyoming, Utah, Idaho & Montana (Geological Society of London Archives)



Edward Drinker Cope (1840-1897) Photograph taken c. 1885 by Frederick Gutekunst (public domain)



Othneil Charles Marsh (1831-1899) Photograph taken between 1865 and 1880. Source: Library of Congress Prints and Photographs Division (public domain)



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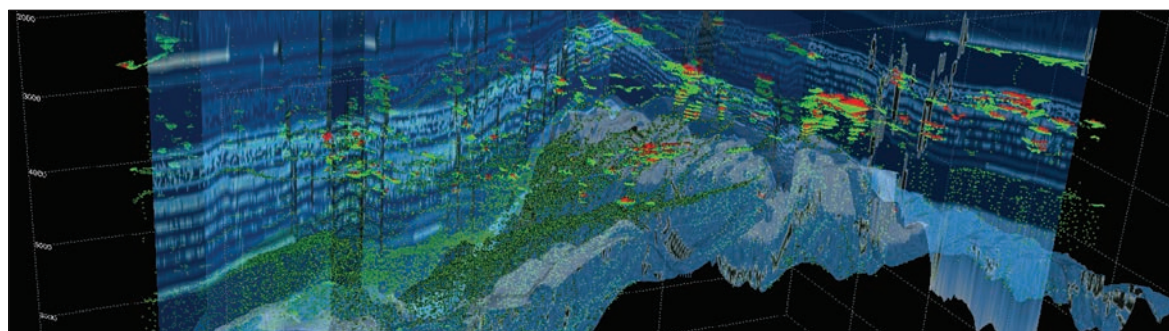
Call for Abstracts – Deadline: 10 April 2020

Basin and Petroleum Systems Modelling

Best Practices, Challenges and New Techniques

16-18 September 2020

The Geological Society, Burlington House, Piccadilly, London



The prediction of viable petroleum systems is critical to meet the growing energy demand. This meeting will discuss the importance of Basin and Petroleum System Modelling (BPSM) in petroleum systems evaluations, focussing on best practices, recent developments, and opportunities for the future.

New and improved digital capabilities have enabled a more integrated approach to petroleum system analysis; therefore, the impact of newly available data and technologies in BPSM will be reviewed. As the energy sector shifts from traditional hydrocarbon to alternatives, and new disciplines such as carbon capture and storage emerge, we will look at novel and innovative uses of BPSM.

Key Topics:

- **Best practices in different exploration scenarios:** mature, frontier, and unconventional areas
- **Effectiveness of modelling geological processes:** heat flow; erosion; kinetics; thermal conductivity
- **Charge and migration modelling**
- **New techniques in BSPM**
- **Integration with other disciplines:** carbon capture and storage; reservoir engineering; geothermal
- **Dealing with predicted risk and uncertainty**
- **Case studies**

The conference will bring together professionals from academia, government agencies, and industry to discuss BPSM through a series of presentations and panel discussions, suitable for both a specialist basin modeller and for a general exploration geologist. A dedicated student poster session will encourage participation from a new generation. The meeting will include an optional one-day field trip to the classic petroleum geology outcrops of Dorset.

Call for Abstracts:

Please submit talk or poster abstract to sarah.woodcock@geolsoc.org.uk by 10 April 2020.

For further information please contact:

Sarah Woodcock, The Geological Society, Burlington House, Piccadilly, London W1J 0BG.
Tel: +44 (0)20 7434 9944



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Editor writes: Please note, due to the ongoing situation surrounding the spread of the coronavirus that causes COVID-19, many upcoming events are likely to be cancelled or postponed. Please visit www.geolsoc.org.uk/events for the latest information.

In addition, we apologise for the error in calendar for the March issue, which featured events from February.

ENDORSED TRAINING/CPD AND EVENTS

MEETING	DATE	VENUE AND DETAILS
POSTPONED: West Midlands Regional Group: Cold supraglacial volcanic deposits and their effects on glacial ablation	14 April	Evening lecture Venue: St Martin in the Bull Ring, Birmingham
Geological Society Discussion Group: Contaminated land, is it all bad?	15 April	Evening meeting Venue: The Geological Society, Burlington House, London
POSTPONED: Geological Society Public Lecture: Responsible manufacturing – getting it right from the start	20 April	Afternoon & evening lecture Venue: The Geological Society, Burlington House, London
POSTPONED: Thames Valley Regional Group: Wing interglacial deposits – the forgotten SSSI	22 April	Evening lecture Venue: RISC, Reading
Primary Geology Rocks! Free primary teacher CPD	23 April	Workshop Venue: The Geological Society, Burlington House, London
POSTPONED: SEPM Sedimentary Geosci Congress 2020	26-29 April	Conference Venue: Flagstaff, Arizona, USA
POSTPONED: Hydrogeological Group: The hydrogeology of sandstones	28-29 April	Conference Venue: The Geological Society, Burlington House, London
Educator's Event: Lapworth Museum teacher training	30 April	Workshop Venue: The Lapworth Museum, University of Birmingham
North West Regional Group: The engineering geology of Florida	30 April	Evening lecture Venue: The Windmill Inn, Tabley, Knutsford

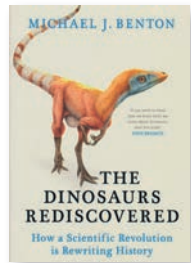
STICKS AND STONES



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BOOK REVIEWS

The Dinosaurs Rediscovered: How a Scientific Revolution is Rewriting History



The Dinosaurs Rediscovered has one core message to convey, and does so very effectively: over the past 40 years science has pushed back speculation in dinosaur palaeontology. Or to put it another way, a field that used to be criticised by others as ‘stamp collecting’ has become dominated by researchers applying new techniques and rigorous methodologies to create evidence-based insights into prehistoric life.

Mike Benton will be known to many as not only a preeminent palaeontologist and a key faculty member behind Bristol University’s world-class palaeobiology research group, but as a skilled science communicator. This book clearly demonstrates his skills in both areas.

Unlike some previous titles from well known palaeontologists, this is neither an updated retelling of the story of the dinosaurs or a book-length case for a reevaluation of a particular area of the field. Instead it is a compelling and concise primer on the current state of dinosaur science.

Broken into chapters that each tackle a ‘big question’, Benton’s book builds a coherent narrative that tracks the evolution of dinosaur palaeobiology as a discipline from around 1980 to the present day. Those familiar with the field from undergraduate studies during that period will find a good mixture of familiar theories peppered with, or in places superseded by, cutting edge recent research.

From cladistic methods for creating new dinosaur family trees to engineering approaches to understanding feeding and locomotion, and from bone histology insights about growth and physiology to analyses that demonstrate dinosaur colour for the first time, Benton brings the day-to-day and year-to-year news from the field up to date.

For anyone wishing to delve deeper

there are a good number, but not too overwhelming a number, of suggested sources for further reading. These range, as the book does, from seminal papers that altered the course of dinosaur studies decades ago to papers from the past few years that you are unlikely to have heard of if you are not an active researcher.

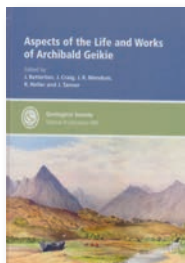
If you already have good knowledge of dinosaur research then this book may be too light on in-depth information for you, but the quality of the writing is such that you’ll most likely be hooked enough to be swept along to the end in the same way as any other reader.

In short, an excellent book for anyone still fascinated by dinosaurs but not actively following developments, or indeed an excellent gift for anyone considering studying dinosaur palaeontology.

Reviewed by **Les Hopper**

THE DINOSAURS REDISCOVERED: HOW A SCIENTIFIC REVOLUTION IS REWRITING HISTORY by MICHAEL J. BENTON, 2019. Published by: Thames and Hudson 336pp (hbk) ISBN: 9780500052006 List Price: £24.95. W: <https://thamesandhudson.com/9>

Aspects of the Life and Work of Archibald Geikie



This book examines the life of Sir Archibald Geikie. It includes non-specialist accounts of field excursions and meditations on the compatibility of the fossil record with the biblical account of creation. The book provides an introduction to the archive at Haselmere Museum that includes unpublished papers, correspondence and works of art that will be an invaluable source for researchers.

Geikie was fortunate in his mentors. The young Geikie’s geological interest was nurtured by Hugh Miller, who gave him access to the Royal Society of Edinburgh, where he presented the results of his early geological research. While still a young

geologist, Geikie developed a close friendship with Murchison that opened up big career opportunities for him. However, this appears to have come at some cost of scientific integrity and the book could have explored these aspects of Geikie’s career further.

It would have been interesting to enlarge on the Survey’s mapping of the Southern Uplands. In a premonition of his work on NW Scotland, Geikie failed to recognise stratigraphic repetition by faulting and it was Charles Lapworth who pointed out the Survey’s errors. Today, no one would argue that Murchison was right about NW Scotland, but to describe his interpretation as a blunder raises the question of whether a scientific theory can be right or wrong. I would argue that major gaps in geological knowledge at the time of Murchison’s death prevented him from coming to a complete understanding of the geology. The endowment of the Chair of Geology at Edinburgh University by Murchison for Geikie would have been worthy of larger treatment in the book, because Murchison’s motivation was apparently to ensure the continuing support of his flawed hypothesis.

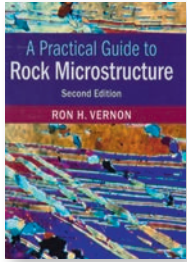
Geikie also made important contributions in areas of igneous and glacial geology, continental erosion in the USA, mineralogy and petrology; perhaps significantly—all areas in which Murchison did not have a prior interest. At a time when pencil and water colour sketches were the only way for geologists to record field observations, Geikie stood out as a talented artist with his own style of landscape painting and his depiction of rural scenes shows the influence of his uncle and Scottish Academician, James Geikie. Geikie also passed on his experience, doing much to popularise geology and to promote women geologists. Other people, including the gifted mineralogist Matthew Forster Heddle, benefitted from his support; however, it is hard to avoid the conclusion that underneath it all lay a single-minded careerist.

Reviewed by **Peter Gutteridge**

ASPECTS OF THE LIFE AND WORKS OF ARCHIBALD GEIKIE by J. Betterton, J. Craig, J.R. Mendum, R. Neller & J. Tanner (eds) 2019, Geological Society of London SP 480, 406 pp. (hbk.) List Price: £110.00 Fellow’s price: £ 55.00 W: <https://www.geolsoc.org.uk/SP480>



A Practical Guide to Rock Microstructure (Second Edition)



This is a substantial, almost 'coffee table' sized, book that is intended '... to help you interpret what you see when you look at thin and polished sections ...'. The text, clear and

well written, is appropriate for its target audience (senior geoscience undergraduates and above) and, as the author acknowledges, much of the content would also be relevant to material scientists involved in the study of ceramics, glass and metals.

Compared to the first edition (2004), this edition has more figures (up by about 10%), and the photomicrographs - key to the book's 'practicality', though much the same size as in the previous version - appear clearer and somewhat sharper, at least to this reviewer's eyes. All the figures have informative captions, which include the linear dimension of the image where appropriate. The text has been partially re-written and in places expanded and the reference list has grown to include works up to and including 2016.

The substance of the book is undoubtedly the chapters on the textures of igneous, metamorphic and deformed rocks. There is also a chapter on sedimentary rocks, but this is rather short and, to this reviewer's mind, rather superficial, especially when compared to the coverage given to the 'hard' rocks.

Complex relationships (e.g. as between temperature and the rates of nucleation and crystal growth) are generally explained by way of numerous clear and well-argued diagrams - these invariably repay close and careful study. The treatment is generally discursive, and accordingly there appears to be only one mathematical equation (it's on page 30 and forlornly labelled equation 3.1...), an approach that will certainly endear it to much of its target audience.

There are few rivals to this work as a working text. Available competitors lack either the breadth and/or depth of coverage and/or the comprehensive coverage of photomicrography and all are now, in any case, rather long in the tooth (dating mostly from the 1990s).

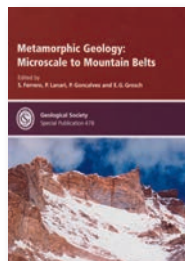
One small point: the link on page iv supposedly to 'additional resources' appears to be empty (accessed 9th October 2019).

One is never sure whether it is worthwhile upgrading from a first to a second edition. In this case it is suggested that you pass your old copy on to a deserving undergraduate and buy the new edition for yourself! Colleagues studying igneous and/or metamorphic rocks will want their own copy to hand and institutional libraries should certainly have a copy in their collection.

Reviewed by **Trevor F. Emmett**

A PRACTICAL GUIDE TO ROCK MICROSTRUCTURE (Second Edition) by RON H. VERNON, 2018. Published by Cambridge University Press 440pp (hbk) ISBN: 9781108427241 List Price: £74.99. W: www.cambridge.org/9781108427241

Metamorphic Geology: Microscale to Mountain Belts



When the first of the Geological Society's special publications was published in 1964, a book containing a selection of scientific papers on a theme was the only practical way to get an overview of a subject. In today's world of 'online first', preprint servers and more, do these volumes still have a role to play?

This, the 478th volume, ranges widely over the complicated topic of rocks that change, tracing the advances made in the last 30 years. The book is anchored in rocks and minerals and contains many attractive photomicrographs, some with laser pits from analysis. On the microscale, it shows how advances in analytical instruments and computer-aided calculations can give detailed maps of mineral composition and relate these to the pressure and temperature conditions under which they formed. This linkage has moved beyond simple assumptions of chemical equilibrium and now considers the role of factors such fluid flow, kinetics and nucleation in the growth and destruction of metamorphic minerals.

It's long been known that tiny grains have big implications; for example, micro-diamonds or coesite inclusions in eclogites indicating very deep burial. One paper describes how in

high-grade rocks dusty-looking garnets may contain 'nanogranitoids'. These tiny samples of now-crystallised magma can give useful information about how the rock itself melted. This paper sent me off on a successful hunt in some old thin sections.

Many of the latest hot topics in the subject are touched on, from how rapid metamorphism can be to evolving ideas that challenge the assumption that measured pressure is always a function of depth and show localised sources of stress may be important.

The final section shows how regional metamorphic studies can trace the history of mountain belts from the summit of Mount Everest to a range of other places around the globe.

The choice of papers and excellent introductory chapter, stylishly ending with a quote from T. S. Eliot, is what makes this a book worth having. An online search could provide the papers, each with a microscopic focus on a particular area. But it's the expert editing that joins them together, giving the reader a birds-eye view of the heights the subject has reached and glimpses of the undiscovered peaks beyond.

Reviewed by **Simon Wellings**

METAMORPHIC GEOLOGY: MICROSCALE TO MOUNTAIN BELTS Edited by S. Ferrero, P. Lanari, P. Goncalves and E. G. Grosch 2019. Published by: The Geological Society 482pp (hbk) ISBN: 9781786204004 List Price: £120.00 W: www.geolsoc.org.uk/SP478 W: www.cambridge.org/9781108427241

BOOKS FOR REVIEW

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

- ◆ **NEW! Early Neogene Stratigraphy and Palaeoceanography of Trinidad, West Indies: A Fresh Perspective**, by Sadie Samsundar, Brent Wilson and Philip Farfan, Nova Science Publishers 2020, 109pp, ebook.
- ◆ **NEW! Applied Concepts in Fractured Reservoirs**, by John C. Lorenz and Scott P. Cooper, Wiley Blackwell 2020, 211pp, hbk.
- ◆ **NEW! Introducing Large Rivers**, by Avijit Gupta, Olav Slaymaker and Wolfgang J. Junk, Wiley Blackwell 2020, 288pp, pbk.
- ◆ **NEW! Rivers in the Landscape**, by Ellen Wohl, Wiley Blackwell 2020, 500pp, pbk.

READERS' LETTERS

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

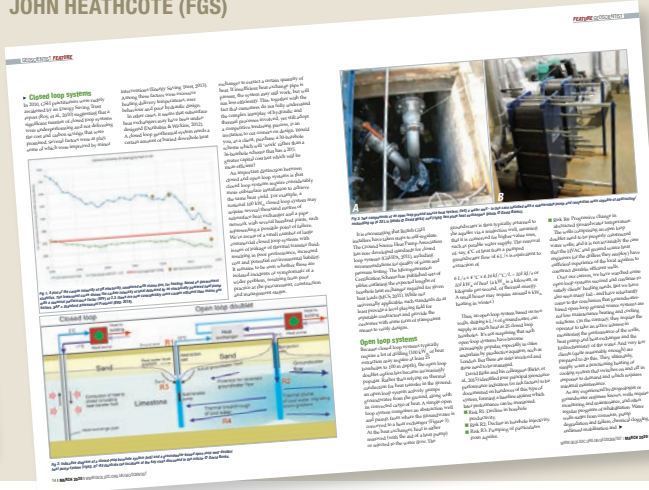
HEAT POLLUTION

Dear Editor, I enjoyed the article by Banks and Birks in the March issue of *Geoscientist*. Although the authors are correct in saying that heat is not a pollutant per se since it is not a substance, the law is quite clear that heat can cause pollution. Directive 2000/60/EC is incorporated into UK law and Article 2(33) says - 'Pollution' means the direct or indirect introduction, as a result of human activity, of substances or heat into the air, water or land...'



Because I'm a hydrogeologist, I decided to go for a shallow loop for my ground-source heat pump. The geology where I live is very complex and poorly known - I was not wishing to pay to find out the hard way! There's bituminous shales, a rather hard conglomerate, or Moine psammite to choose from, with an unconformity and faulting to complicate things.

JOHN HEATHCOTE (FGS)



THE MESSAGE FROM CLIMATE SCIENCE

Dear Editor, Since the first World Climate Conference (1979) about the role of our emissions in global warming, the powerful combination of research and observations, involving tens of thousands of scientists around the world, has proved conclusively that emissions from human activities are changing the climate. Furthermore, geological research makes equally clear the primary role of CO2 in changing Earth's pre-Pleistocene climates, and its subsidiary role in enhancing the effects of orbital change during the Pleistocene Ice Age. Rather than rubbishing climate models, it would be wise to remember that petroleum companies still use climate models as exploration tools, just as I did in the 70s and 80s during my 12 years as a researcher in the petroleum business (6 each with Exxon and BP).

Given (i) the message from climate science that humans have been the main cause of warming since 1950 (the period in which

humans burned more than 85% of the fossil fuels ever used), and (ii) the message from geology that whenever the temperature rose by 2-3°C the sea level rose by 4-9m, we need to act quickly to increase renewable energy sources and cut fossil fuel use - the main source of CO2. Young scientists are striving to invent this new future. We will need to shift global subsidies from fossil fuels to renewables to speed the infrastructure transition so that we can all safeguard the interests of our grandchildren. It might help if petroleum companies saw themselves as energy companies, not just as sources of fossil fuels. In any case, we should not demonize those who work for the fossil fuel industry, whose products we still need daily, and will do for years to come - even if in progressively smaller amounts.

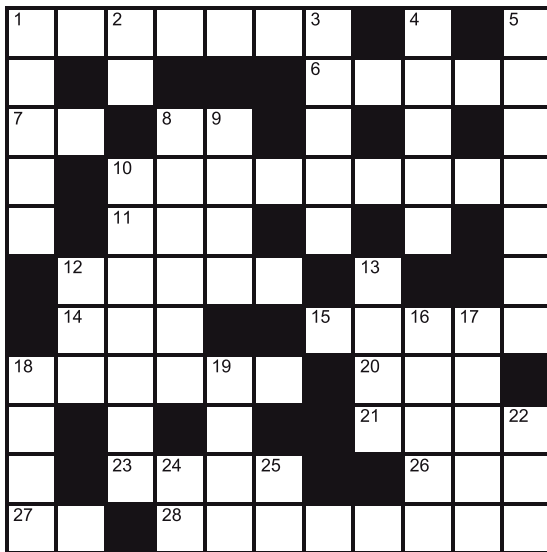
COLIN SUMMERHAYES (FGS)



Read the latest news in *Geoscientist*, when you join the GSL

Crossword

By Bindweed



Across

- 1 See 13 Down
- 6 Tail-like appendages especially in certain arthropods (5)
- 7/27 Painter of The Second and Third of May 1808 (4)
- 8 See 2 Down
- 10 Polar Medal winner who spent a winter alone on the Greenland icecap (9)
- 11 Multiples of 3600 seconds (3)
- 12 Pilot on the 13d/1ac expedition later Air Vice Marshall and Priest
- 14 Singles have 45 of these (3)
- 15 Polar Medal winner and meteorologist on the 13d/1ac expedition
- 18 Leader of the 1933 Greenland Expedition after the death of 13d/1ac
- 20/22d Type of aquatic gastropod (6)
- 21 Prefix meaning 'all'
- 23 County town of County Kildare (4)
- 26 Time zone -7 UTC (3)
- 27 See 7
- 28 Igneous rock formed by precipitated crystals (8)

Down

- 1 Lyell medal winner and discoverer of the Skaergaard intrusion (5)
- 2/8A A disorderly outburst (2-2)
- 3 Explorer and biographer of 13d/1ac (5)
- 4 Fish popular with bears (5)
- 5 Polar Medal winner and surveyor of the 13d/1ac expedition (7)
- 8 Rogers and Hammerstein composition (2-2-2)
- 9 Drive out or expel (4)
- 10 Polar Medal winner who coined the phrase "The Jungle is Neutral" (7)
- 12 Water free (3)
- 13/1A Leader of the 1930 Arctic Air-Route Expedition (4, 7)
- 16 One of the bracts enclosing a grass flower (5)
- 17 E.g. Max or Plank (5)
- 18 Corundum mineral mined in Greenland (4)
- 19 A Hawaiian party (4)
- 22 See 20 Across
- 24 Element 89 (2)
- 25 Metal found in samarskite (2)

Solutions March | **Across:** 1 Phanerozoic 8/7 core 9 enamel 12/19 stylists 14 pi 15 Armorican 18/4/25 smouch 21 zealot 26 OO 27/16 Northampton Ironstone **Down:** 1 Precambrian 2 hen 3 Eye 5 icy 6 Collyweston 10 Acmeist 11 Leibniz 12 spa 13 tin foil 17 RMS 20/24 stoat 22 elm 23 OOO

The Geological Society Call for meeting proposals

The Geological Society invites meeting proposals for 2021 to be held at Burlington House, London.

For more information please visit
www.geolsoc.org.uk/meetingproposal-submit



DISTANT THUNDER

An everyday story of geological folk

Geologist and science writer Nina Morgan tunes in to the UK's longest running radio soap

Originally produced with collaborative input from the Ministry of Agriculture, Fisheries and Food, *The Archers*, the popular UK radio soap first broadcast in 1950 and now attracting an estimated audience of over 5 million listeners, was conceived as a means of disseminating information to farmers and smallholders to help increase productivity in the postwar era of rationing and shortages.

But whether the producers knew it or not, the programme also provides a perfect medium for disseminating geological concepts. Back in 1993, Hugh Torrens [b. 1940] and Bernard Besly [b. 1955], both then based in the Geology Department at Keele University, worked through piles of 'palaeoscriptological' evidence, augmented by information provided by the then agricultural story editor Anthony Parkin [1926 – 2007], to

produce a geological map of the area around Ambridge, the Archer's imaginary home village in the fictional county of Borsetshire.

Palaeoscriptology

A combination of contextual clues, regional geological information and chance remarks slipped into the script led Besly and Torrens to the conclusion that the local solid geology must consist of Jurassic and Triassic rocks. Additional clues in the dialogue made it possible to identify the underlying geology in greater detail. For example, mentions of the heavy blue clay – cold to warm up and too wet to work – that so frustrated fictional farmer, Phil Archer, from 1950 until his (real and fictional) death in 2009, suggest the presence of the Lower Lias. With the help of a highly detailed topographic map, and aided and abetted by chance remarks made by Ambridge's feckless farmers, the Grundys, the pair were able to draw on their mapping skills to come up with a

plausible geological map of the area around Ambridge.

Elaborating on the evidence

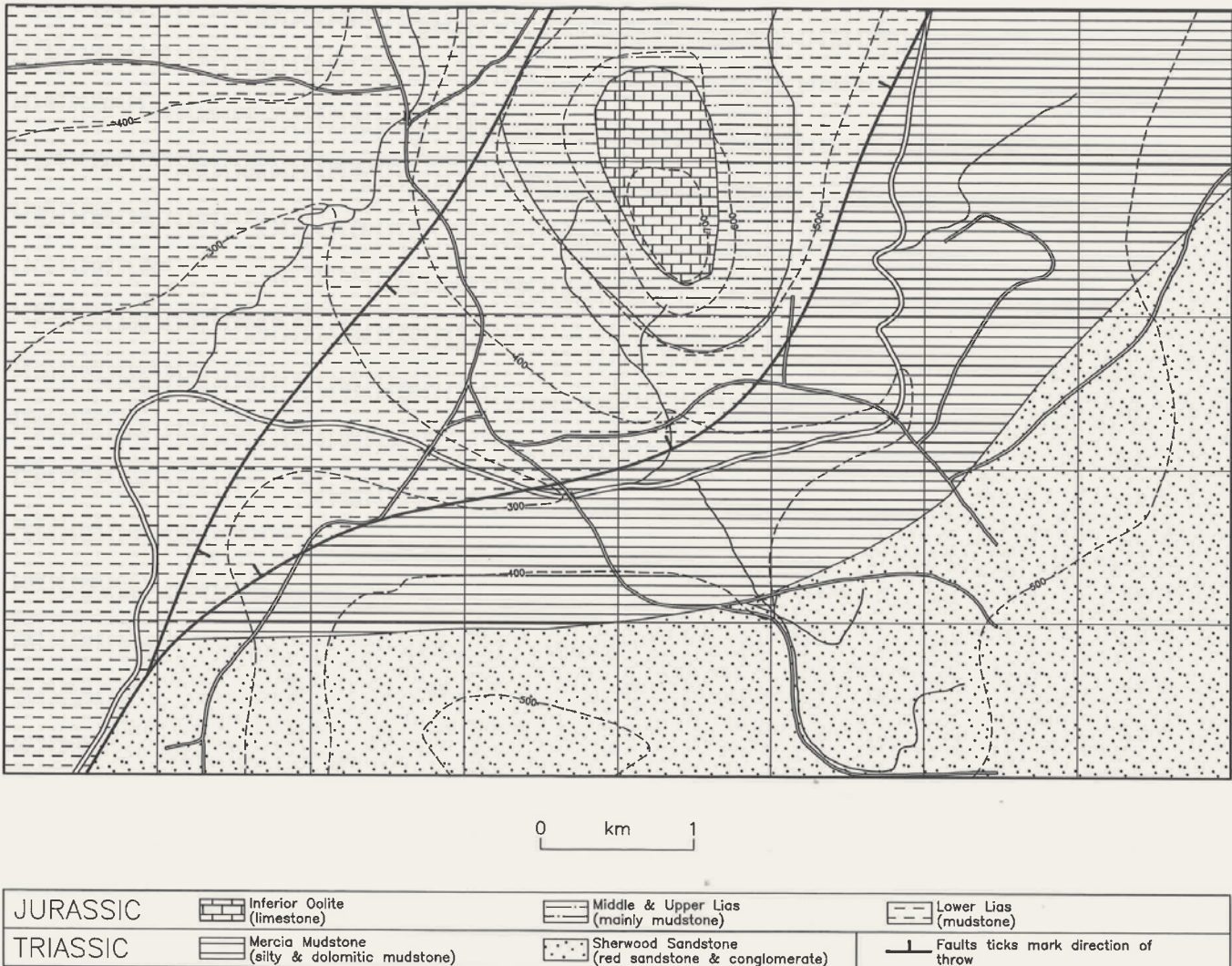
Torrens's and Besly's map and interpretation was first reported – or perhaps, more accurately, misreported -- in the October – November 1993 issue of *The Yew Tree*, the Community Magazine of Keele Parish. It also drew a big crowd at the 1993 British Association Annual Meeting held in Keele, where Torrens and Besly presented the results of their research in a poster. Illustrated by photographs taken around Blockley in Gloucestershire, the poster revealed further geological details, including the suggestion that the geology around the local Ambridge landmark, Lakey Hill, probably begins with Lias clays, and passes up into cappings of Oxfordshire-Warwickshire oolites, with an important Marlstone Rock ledge in between. This scenario would allow for the Coal Measures and the New Red Sandstone to appear by faulting in one quarter of the mapped area.

Their map led the geologist Eric Robinson





GEOLOGY OF AMBRIDGE



Map created by Hugh Torrens and Bernard Besly for their poster at the 1993 BAAS meeting in Keele

[b. 1929] to speculate that the local building stone in Ambridge might consist of either Triassic Arden Sandstone (either the green, brown, buff or mauve varieties) or a buff coloured sandstone from the Upper Carboniferous Keele Formation, dug from quarries in the surrounding woodland where, until recently, gamekeeper Will Grundy reared his pheasants. There might even, Robinson hypothesised, be scope for an oil discovery in the area, similar to the Eaking oil field in Nottinghamshire, which produced the bulk of the UK's indigenous crude from a Carboniferous reservoir during the Second World War.

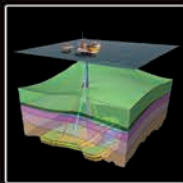
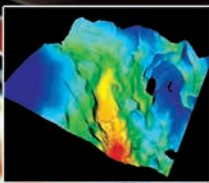
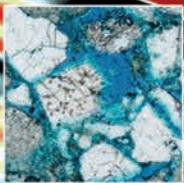
Tune in

All this speculation might seem slightly silly, but it does have a serious side. Incorporating geology into popular programmes like *The Archers* is a really effective form of science outreach. And geologically speaking, picking up on the clues provided – either intentionally or not – is a great way to sharpen up your geological mind. No fooling!

End notes: I am grateful to Hugh Torrens for providing copies of the article, Larkin' about on Lahey Hill, from the October – November 1993 issue of *The Yew Tree*

along with a copy of the map of Ambridge presented at the 1993 BA meeting; and to Bernard Besly for helpful discussions. Other sources include News from Keele by Eric Robinson, *Geology Today*, 9/6 1993, pp 207-208; Wikipedia entries about *The Archers* and information about the programme on the BBC Radio 4 website.

* **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



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Call for Abstracts – Extended Deadline 30 April 2020

Development and Production Geology of Carbonate Reservoirs

28-29 October 2020

The Geological Society, Burlington House, Piccadilly, London



Carbonate reservoirs constitute some of the most important sources of global oil and gas production. They form the world's largest oil and gas accumulations, the world's highest-producing fields, and have some of the longest production histories. Significant new carbonate discoveries continue to be made, and carbonates are also a source of geothermal energy or may be utilised for gas storage.

Successful development of supergiant carbonate reservoirs can result in plateau production that may last for decades, giving high ultimate recovery factors. But, carbonate reservoirs can also be some of the most complex in terms of reservoir quality and heterogeneity. Many give disappointing ultimate recovery factors and some are deemed uncommercial with current technologies. Fundamental geological understanding, sufficient and appropriate geological and dynamic data, and the construction of effective models are the keys to optimising the exploitation of such reservoirs.

This conference will focus on how lessons learned from more than a century of discovery, appraisal and development of carbonate reservoirs may be applied to emerging discoveries. It will bring together the experiences of diverse operators with an objective of highlighting best practices for the geological characterization of carbonate reservoirs from appraisal to production.

Potential session themes:

- Excess permeability – blessing or curse?
- Pores vs stratigraphy – what controls dynamic reservoir behaviour?
- Reservoir analogues – how useful are they?
- Static modelling of carbonate reservoirs – how predictive can we be?
- Multiscale/multidisciplinary dynamic reservoir characterization – how can we integrate geology effectively?
- Improving recovery/revitalising old carbonate fields – adding value through geological understanding.

Planned field trips:

The Carboniferous platforms of Derbyshire, led by Pete Gutteridge, Cambridge Carbonates.
Zechstein carbonates of the north-east of England, led by Geospatial Research Ltd.

Call for Abstracts:

Please submit talk or poster abstract to sarah.woodcock@geolsoc.org.uk by 30 April 2020.

For further information please contact:

Sarah Woodcock, The Geological Society, Burlington House, Piccadilly, London W1J 0BG.
Tel: +44 (0)20 7434 9944



At the forefront of petroleum geoscience

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#PGCarbonateReservoirs20

OBITUARY

Paul Howard Bridges 1948-2017

Paul Bridges grew up in Bath and obtained a first class degree in geology from Swansea in 1969 before embarking on a PhD at Reading where he studied the sedimentology of the Llandovery transgression in the Welsh Borderlands. Everyone who knew him during his early career was struck by both his capacity for meticulous, painstaking and careful work and his kind, generous and thoughtful character. He was just a delightful person to have as a friend and colleague, never interested in being in the limelight, but always interested in helping others to complete whatever job needed to be done.

Derby

When he completed his postgraduate studies in 1972 he accepted a lectureship in palaeontology at Derby College of Art and Technology. And there he stayed for his entire career, helping to steer it through successive stages in its evolution until and beyond when it became a University in 1993.

Research and Teaching

During the 1970s to 80s he published on his Llandovery work and on various aspects of shallow marine and tidal flat sedimentology. He also co-authored *A Dynamic Stratigraphy of the British Isles*, his care, attention to detail and enthusiasm being crucial to the completion of the textbook. In the 1980s and 90s he concentrated on the evolution of Carboniferous mud-mounds

Sedimentologist, teacher and university manager known and loved for his helpful and self-effacing manner



and co-edited the IAS Special Publication *Carbonate mud mounds: their origin and evolution*. Later, he increasingly focussed on improving the quality and administration of teaching both within his institution and nationally. He was a great teacher, organised, enthusiastic and encouraging. Generations of students were influenced by his sound advice and set on successful career paths by him.

Administration

His interest in course structure and in improving the flexibility of the educational experience led him, by the 1990s, to become Dean of Academic Planning and then Dean of Modular Studies. Outside the University he was a leading light in the Northern Universities Consortium for Credit Accumulation and Transfer (NUCCAT) and the UK Credit Forum, becoming chair of these organisations.

However, he continued to foster research within the University and by when he retired he had become Head of Research (and leader for RAE/REF) as well as University Risk Manager, Company Secretary and Clerk to the Governing Council. All this hard work culminated in the award of an MBE in 2013 for his services to education. But more importantly, he had a real influence throughout his life on all those that knew him, setting us all an example of generosity, kindness and diligence.

Interests

He retired in 2013, becoming an Emeritus Professor, and was awarded an Honorary Doctorate from the University of Derby for his outstanding contribution to the institution. He continued his interests in gardening and running. He was also a very talented artist and a keen

Aston Villa fan. He did a huge amount of voluntary work for local groups including Derby Cathedral and St. Joseph's Church. He is survived by his wife Madeleine and son Ashleigh and will be sadly missed by all.

By Roger Anderton



The Society notes with sadness the passing of:

Ashworth, Kevan*
Chambers, Henry*
Donovan, Desmond*
Glennie, Ken
Hunt, Albin Digby*
Holland, Charles
James, Ella*
King, Cuchlaine*
Laughton, Anthony
Morey, Colin Robert*
Parvizi, Fereydoun *
Pascall, Carolyn*
Potter, John F
Reading, Harold
Rhodes, Frank*
Snelling, Norman John
Urquhart, Elspeth
Williamson, Iain

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

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

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

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

OBITUARY**Harold Garner Reading (1924-2019)**

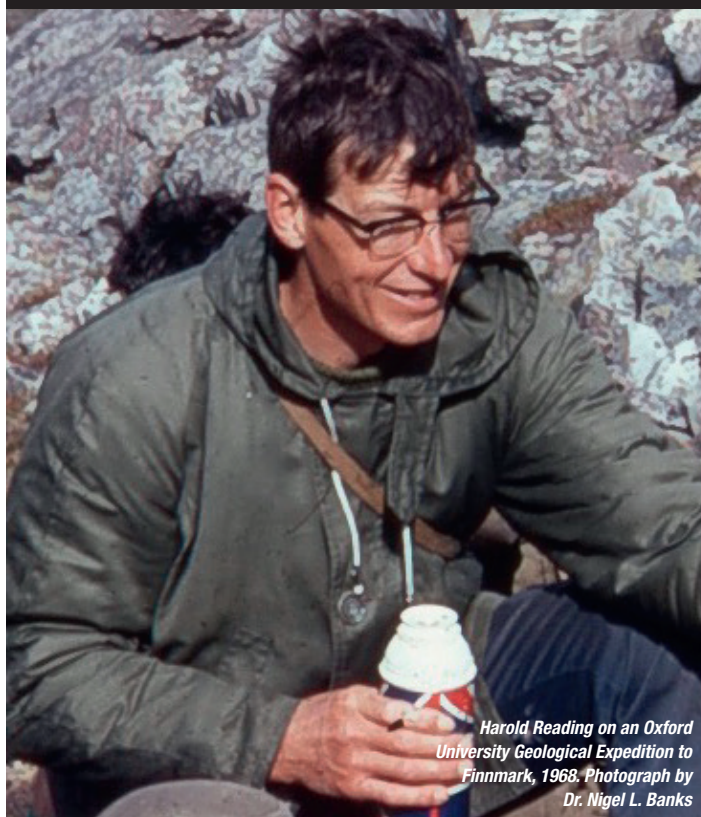
The name Harold Reading will conjure up different images for different people, but it will be instantly recognized by anyone who has ever studied sedimentary facies analysis. His first disciple, Roger Walker, acknowledges the loss of 'the father of Facies Analysis', and a legacy that stretches to sedimentological great grandchildren through the lineage of PhD students.

'Harold's book'

For many, recognition will be based mainly on Harold's book, otherwise entitled *Sedimentary Environments and Facies* (1st and 2d eds.), or its latest (1996) version retitled *Sedimentary Environments: Processes, Facies and Stratigraphy* (3d ed.). For others, it will be the name inextricably linked with the International Association of Sedimentologists (IAS), for which he worked tirelessly during its formative years, occupying the positions of publications secretary, general secretary, and president.

He was also central to the birth and growth of the British

“ HAROLD WILL FOREVER BE RECOGNIZED AS AN INSPIRATIONAL LEADER AND VISIONARY... AND IN BEING ONE OF THE FINEST ROLE MODELS OF A TRUE GENTLEMAN AND HONEST PROFESSIONAL. ”

Pioneering sedimentologist who inspired generations of students

Harold Reading on an Oxford University Geological Expedition to Finnmark, 1968. Photograph by Dr. Nigel L. Banks

Sedimentology Research Group (BSRG). During his 34-year career at Oxford University (1957-1991) he guided innumerable undergraduates and postgraduates through their initial geological training with many going on to distinguished careers in virtually all branches of the geological sciences and beyond.

The birth of sedimentology

It is sobering to realize that the subject of sedimentology, as we know it today, did not exist when Harold first studied geology. Furthermore, it was only by chance that he ended up studying geology at all. It was even more fortuitous in 1957, after an unplanned repatriation to Oxford for

family reasons, that he was offered a position as lecturer in vertebrate palaeontology.

Fortunately, his interest in sedimentology had already been sparked by his work in Shell and interaction with the burgeoning Dutch school of sedimentology, especially Philip Keunen (University of Groningen) and Marits de Raaf (Shell Research and University of Utrecht). Through an alliance with John Collinson and the late Trevor Elliott ('Sedimentary Research Associates') he maintained his petroleum-related links, preparing many geologists for the massive upsurge in North Sea exploration.

He loved the challenge of teaching professional geologists, mainly because, as

he often said, they taught him so much! He was the recipient of numerous awards from internationally-renowned institutions (see extended online obituary for further details) and was always held in the highest esteem.

Inspirational leader

Despite our sadness, we should celebrate an incredibly rich and productive life that reached all parts of the world. Harold will forever be recognized as an inspirational leader and visionary in the development of sedimentary facies analysis, in the education of generations of students from around the world, and in being one of the finest role models of a true gentleman and honest professional. His legendary support of all students will continue long into the future: be it through those who he directly taught or supervised, or the many more that he influenced indirectly through his work, especially 'the book'. This will remain Harold's most cherished and long-lasting legacy. What a man, what a life and what an enviable legacy!

Harold passed away peacefully at his one and only family home in Upper Wolvercote, Oxford, after a short illness. His wife, Bobbie, pre-deceased Harold, who is survived by his children John, Peter, Caroline and Simon, and by 11 grandchildren.

By Howard D. Johnson

The full version of this obituary can be found online. *Editor*



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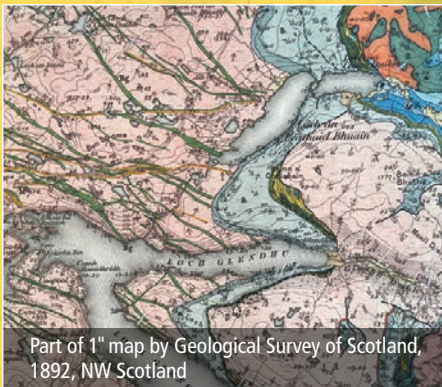
DELINEATION
STRATA
OF
ENGLAND AND WALES,
WITH PART OF
SCOTLAND,
SHOWING
THE COLLIERIES AND MINES,
THE MARSHES AND FEN LANDS, BRIGGS, &C. AS APPEARED BY THE 1844
VARIETIES OF SOIL
ACCORDING TO THE CORRELATION IN THE STRATA,
ILLUSTRATED BY ROBT. HENRY POTTER, SURV.
1870

WILLIAM SMITH MEETING 2020

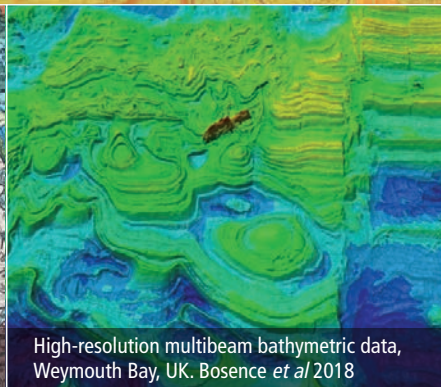
Geological mapping: of our world and others

6-8 October 2020

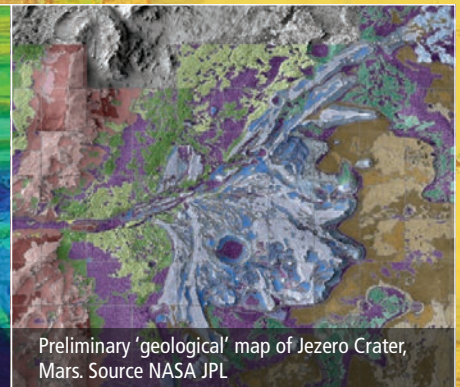
The Geological Society, Burlington House, London



Part of 1" map by Geological Survey of Scotland, 1892, NW Scotland



High-resolution multibeam bathymetric data, Weymouth Bay, UK. Bosenet *et al* 2018



Preliminary 'geological' map of Jezero Crater, Mars. Source NASA JPL

Convenors

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

Further information

For further information about the conference please contact:

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E: conference@geolsoc.org.uk
Web: www.geolsoc.org.uk/wsmith20



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

Confirmed Keynote Speakers

Kathryn Stack (Jet Propulsion Laboratory, NASA)
Marc St-Onge (Geological Survey of Canada)
John Dewey (University College, Oxford)
Mike Daly (President-designate of the Geological Society)
Maarten De Wit (AEON, Nelson Mandela University)

Call for Abstracts

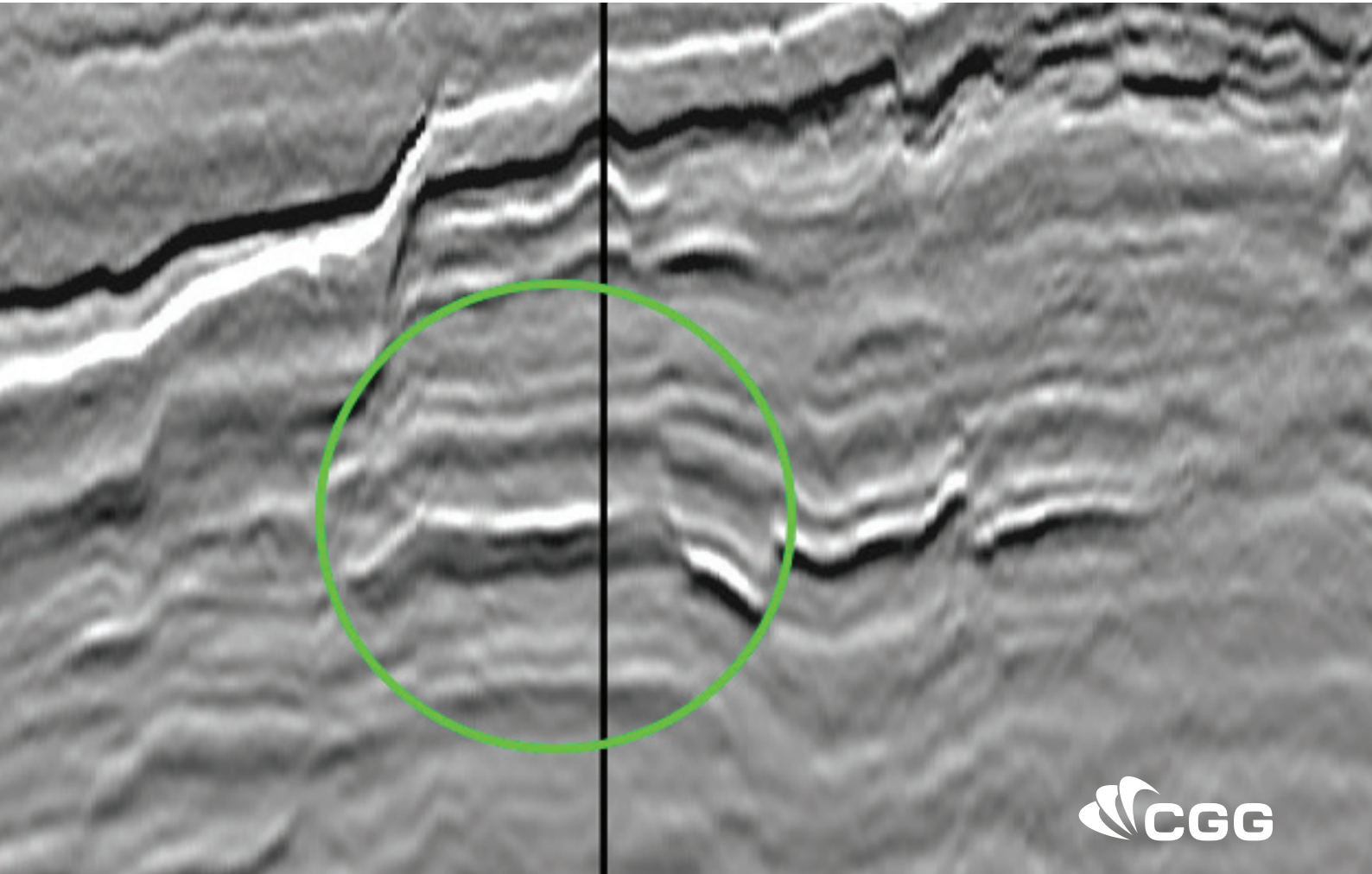
We invite oral and poster abstract submissions for the meeting, and these should be sent in a Word document to conference@geolsoc.org.uk by 30 April 2020. Abstracts should be approximately 250 words and include a title and acknowledgement of authors and their affiliations.





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