GEOSCIENTIST

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The Fellowship Magazine of the Geological Society of London

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[ONE GIANT LEAP: THE MOON LANDING AT 50]

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Ian Selby on the need to take stock of this resource

DIG DEEP
To keep Lyell's notebooks in the UK, urges John Henry

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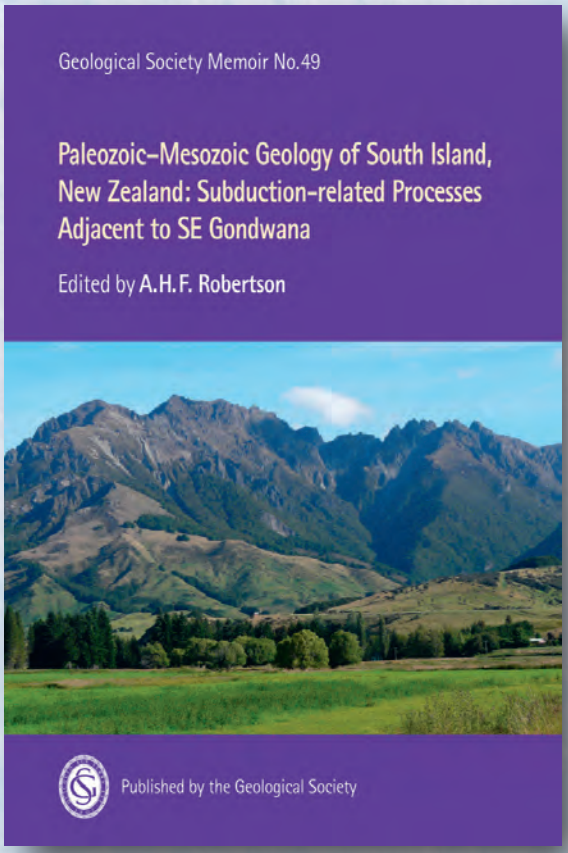
New Title Alert

Paleozoic–Mesozoic Geology of South Island, New Zealand: Subduction-related Processes Adjacent to SE Gondwana



Edited by A.H.F Robertson

NEW

378 pages
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This volume presents a set of research papers that provide new data and interpretations of the Permian–Triassic terranes of SE Gondwana, now exposed in South Island, New Zealand. Following an introduction for general readers, a historical summary and a review of biostratigraphy, the individual papers primarily focus on the Permian magmatic arc of the Brook Street Terrane, the classic Permian Dun Mountain ophiolite and the Permian–Triassic Maitai Group sedimentary succession. The new results emphasize the role of subduction and terrane displacement adjacent to the Permo-Triassic Gondwana margin, and present fundamental insights into three crustal processes: subduction initiation, supra-subduction zone oceanic crust genesis and forearc basin evolution.

Find out more online at: www.geolsoc.org.uk/M0049

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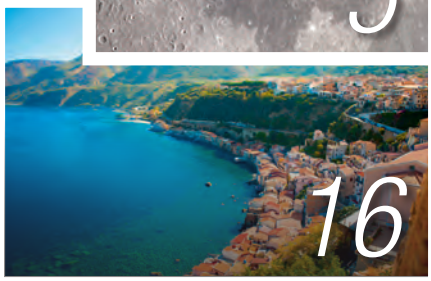


ON THE COVER:

FEATURES

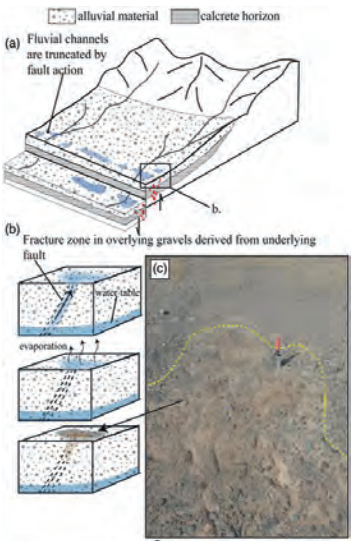
REGULARS

Latest news from the **Publishing House**

Geochemical signature of earthquake-induced surface flooding by mineralized groundwater over the buried Atlántida deposit, northern Chile

By A. E. Brown, P. A. Winterburn and T. Bissig

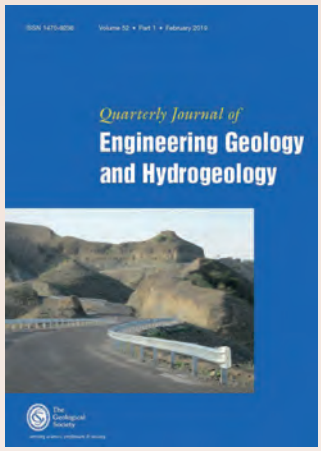
At the buried Atlántida deposit (Cu–Au–(Mo)) in the Atacama Desert of Chile, highly saline pockets of fine-grained material 10 cm–3 m in diameter were identified on the alluvial surface using remote sensing and detailed regolith mapping. The median salinity (NaCl dominant) of the saline pockets is 2.2% compared to background alluvial material with a median salinity of 0.01%. Their distribution along mapped fault structures and the highly saline nature of the material suggest they form as an expression of groundwater forced through fractures to the surface during seismic activity...



Read the full abstract and paper in the Lyell Collection
https://geea.lyellcollection.org/content/early/2019/05/20/geochem2018-065

The engineering geology of concrete in hot drylands

By P. G. Fookes and E. M. Lee



In hot drylands the main causes of concrete deterioration are physical salt attack by aggressive evaporite salts, reinforcement corrosion (e.g. carbonation, chloride ingress) and aggregate unsoundness. The manufacture of concrete presents more problems than in temperate countries due to the higher ambient temperatures and drying winds, plus windblown salts (mainly chlorides and sulphates). However, it is not just aridity that is significant to concrete in hot drylands, but also the availability of moisture and the duration of moist conditions. This paper draws upon the lifetime's experience gained by the lead author (PGF) and aims to provide a basic introduction to the 'engineering geology of concrete' for hot drylands. The focus is on the Middle East and North Africa, but the general messages have broader applicability.

View in the Lyell Collection now
https://qjegh.lyellcollection.org/content/early/2019/05/17/qjegh2018-185

> AS WE CELEBRATE THE 50TH ANNIVERSARY OF MAN'S FIRST STEP ON THE MOON, WE MUST CONCENTRATE EFFORTS TO PROTECT THIS GREAT WILDERNESS

FROM THE EDITOR'S DESK:

Mining the Moon

Five decades after the Apollo missions, lunar exploration is experiencing a renaissance.

The renewed interest is due partly to the 2007 Google Lunar XPRIZE, a competition that challenged privately funded teams to land a robotic spacecraft on the Moon. Several teams took up the challenge, but the $30 million prize money went unclaimed when, after numerous deadline extensions, no team was able meet the final 31st March 2018 launch target. Regardless, several companies that entered the competition still aim to launch missions by the end of 2021.

XPRIZE has been superseded by 'The Moon Race'. With challenges that include building the first artefact made of lunar resources or filling a bottle with lunar water, the competition aims to encourage 'sustainable exploration' of the Moon.

Such competitions are backed by major government agencies, including NASA and ESA. By piggybacking scientific instruments on these private missions, researchers can study topics such as the Late Heavy Bombardment and moonquakes. But, what might tempt private companies to invest? The answer: mining and the lunar economy.

Initial analyses of the Apollo samples implied a largely dry and barren satellite. We now know that the Moon harbours water ice at its poles and within its regolith, in addition to helium-3. These hydrogen, oxygen and helium resources could be harvested to sustain a manned lunar base, for use as fuel back on Earth, or as rocket fuel to power flights farther into the Solar System, with the aim of mining asteroids or even colonising Mars. The lower gravitational pull of the Moon means it would be cheaper to use the Moon as a fuelling base for long-distance space travel than it would be to carry the full fuel load from Earth.

The prospect of mining the Solar system, particularly by private companies, raises numerous ethical questions. Who owns these resources? Who has the right to exploit them? The 1967 United Nations Outer Space Treaty prevents the appropriation of the Moon, or any celestial body, by individual nations, but does not prevent space mining. To establish a regime for Moon use, the treaty was followed in 1979 by the Moon Treaty, which states that all activities must conform to international law, similar to the UN Convention on the Law of the Sea. But the treaty is largely useless in practise because it was not ratified by major space-faring nations, such as the United States, Russia and China.

In a recent study (*Acta Astronautica*, 2019) astrophysicist Martin Elvis and philosopher Tony Milligan argue that more than 85% of the Solar System should be designated 'Space wilderness', to protect celestial bodies from industrial exploitation. Based on humankind's exponential growth and consumption and our inability to foresee the pace of such growth (as evidenced by climate change and over population), they contend that we could burn through 1/8th of our Solar System's resources in under 400 years, leaving just 60 years to transition to more restricted conditions or risk exhaustion. Of course, there are many unknowns, and technological advances will alter the calculations. Still, Elvis and Milligan make a strong argument.

Technology has preceded regulation in space, making rules difficult to enforce. Sustainable exploration will require restraint and international cooperation.

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

SOCIETY *NEWS*

Society's Awards 2020 – Invitation to nominate

Fellows of the Society are invited to submit nominations for the Society's Awards for 2020, writes George Jameson.

The Society has an ambition to see the diversity of nominations to Society medals and funds increase, with the aim of broadening the demographics of those put forward.

As a result, this year the Society undertook a holistic review of its Awards procedures, focusing on the nominations, application, submission, judging and assessment processes and criteria.

As you will see by visiting **www.geolsoc.org.uk/About/Awards-Grants-and-Bursaries/Society-Awards**, we now have one standard nomination form for all of our awards with the exception of the President's award, which now has its own form. Our guidance documents have also been revamped and help to explain how to go about nominating a person you feel is deserving of a Society award.

All of these changes have been captured in our new pdf booklet that can be found on the same page!

Remember nominations must be sent to the Awards Secretary no later than **noon on Friday, 27 September 2019** using the new forms.

Enterprise membership

27 June 2019 was the second international Micro-, Small and Medium-sized Enterprises Day, as designated by the United Nations. In recognition of the impact and importance of engaging with start-up and smaller companies working in the Earth science industry, the Geological Society have announced a new **Enterprise** category, as an extension of its existing corporate membership programme. For a contribution of £500 +VAT companies with up to 10 employees and an annual turnover of under £2 million can join the Geological Society as Enterprise members and have access to the Society's world-class library and other facilities. Enterprise members will receive a copy of Geoscientist magazine, the Society's corporate e-newsletter and will be invited to attend two annual corporate networking events.

For more information, please contact the Development Team:
T: + 44 (0) 20 7434 9944
E: development@geolsoc.org.uk

Society Discussion Group

Meetings of the Geological Society Discussion Group are 18.30 for 19.00, when dinner is served. Attendance is open to all members of the Society. For up to date information concerning topics for discussion and speakers, please go to
W: www.geolsoc.org.uk/Groups-and-Networks/Specialist-Groups/Geological-Society-Discussion-Group.

- 18 September - The King's Head, Mayfair
- 23 October - Bumpkins Restaurant, South Kensington
- 4 December - The Athenaeum, Pall Mall

Please contact the Conference Team for more information and to make a reservation. **E:** conference@geolsoc.org.uk

Trustees list 2019-2020

Every year following elections, the Trustees list of the Society changes. Trustees give greatly of their time and effort in representing the Fellowship, and we would like to extend to them a warm vote of thanks.

Trustees of the Geological Society of London 2019-2020

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Office closures

The Society (London and Bath) will be closed all day on Thursday 18 July for staff training.

What your society is doing
at home and abroad

The Petroleum Group

Sarah Woodcock and Lucy Williams provide an update on the Petroleum Group's activities

The Petroleum Group is the Geological Society's Specialist Group dedicated to petroleum exploration and production. Our primary aim is to advance the study and understanding of petroleum geoscience through the organisation of cutting-edge conferences, workshops and publications, and where possible bring together industry and academia. We also seek to collaborate with other groups and organisations where mutual interests overlap.

Since the Group started in 1983, we have convened over 280 meetings, produced 59 Geological Society Special Publications and 25 Petroleum Geoscience thematic sets—quite an archive of reference material, all of which is available through the Lyell Collection. Past meeting abstract books and resources, information on our busy 2019 programme and much more can be viewed at **www.geolsoc.org.uk/petroleum**.

The Petroleum Group Committee currently has 22 members drawn from industry and academia, including our PhD student representative. Companies such as Shell, BP, Halliburton, Badley-Ashton and Sound Energy, as well as the Universities of Liverpool, Heriot Watt and Leeds are represented. We seek to maintain a broad committee, drawing on a range of experiences to ensure we cater for the needs of our community. New committee members are welcomed each year, with a call for applications before September.

We strive to remain relevant to changing times within our industry by ensuring our meeting topics are at the forefront of geoscience innovation and technology. We also aim to ensure that early career geoscientists are represented on the committee and that we will continue to provide cutting edge geoscience through the energy transition.

You don't have to be a member of the committee to contribute. We welcome your ideas and proposals for future conferences, or your participation as a convenor. Meeting attendance counts towards your CPD; important if you are considering Chartership. To find out more about becoming a member of the Petroleum Group or the committee, please contact Sarah Woodcock at: **sarah.woodcock@geolsoc.org.uk**

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New Publications

William Smith's Fossils Reunited

By: Peter Wigley (Editor) with Jill Darrell, Diana Clements and Hugh Torrens

With a Foreword by Sir David Attenborough, William Smith's Fossils Reunited is intended both for the William Smith enthusiast and also for those with a more general interest in the work of this remarkable pioneering geologist. The fossil illustrations and maps in this exquisite volume are aesthetically pleasing in their own right and demonstrate the extraordinary skill of early nineteenth-century engravers and map makers.

View more at: www.geolsoc.org.uk/WSFR

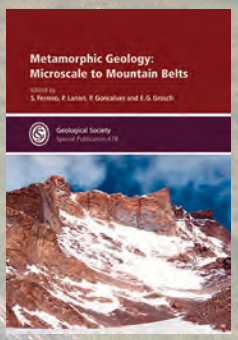
Glaciated Margins: The Sedimentary and Geophysical Archive

Edited by: D. P. Le Heron, K. A. Hogan, E. R. Phillips, M. Huuse, M. E. Busfield and A. G. C. Graham

Understanding the sedimentary and geophysical archive of glaciated margins is a complex task that requires integration and analysis of disparate sedimentological and geophysical data. Their analysis is vital for understanding the dynamics of past ice sheets and how they interact with their neighbouring marine basins, on timescales that cannot be captured by observations of the cryosphere today

View more at: www.geolsoc.org.uk/SP475

Metamorphic Geology: Microscale to Mountain Belts



Edited by: S. Ferrero, P. Lanari, P. Goncalves and E. G. Grosch

In Earth evolution, mountain belts are the loci of crustal growth, reworking and recycling. These crustal-scale processes are unravelled through microscale investigations of textures and mineral assemblages of metamorphic rocks. Multiple episodes of metamorphism, re-equilibration and deformation, however, generally produce a complex and tightly interwoven pattern of microstructures and assemblages.

View more at: www.geolsoc.org.uk/SP478

Visit: www.geolsoc.org.uk/bookshop

or call the Publishing House +44 (0) 1225 445046

Image credit: Staple Tor © Wayne Brittle

Dig deep for Lyell's notebooks

Lyell's notebooks are at risk of export. Support a crowd-funding initiative to keep this valuable resource in the UK, urges **John Henry**

The discoveries and developments of the Victorian period underpin and shape our geological framework: The expansion and refinement of William Smith's stratigraphic concepts, the definition and naming of the eons, eras, systems, series and many stages that are part of our geological DNA and working vocabulary.

Cultural value

Charles Lyell [1797-1875] was a major thinker and influencer in the development of the Earth sciences. Lyell's first edition of his *Principles of Geology* accompanied the young geologist Charles Darwin on his famous voyage of discovery on the HMS *Beagle*.

"'Darwin always believed that his books 'came half out of Lyell's brains'."[1] Lyell was a well-travelled and prolific author of books (6), through several revised editions (30) and numerous journal articles (87)[2]. The twelve revised editions from 1830-1875 effectively trace the progress of geological knowledge in this formative period. Lyell's writings were read widely by the aspiring and influential classes of his period and thus have significant wider cultural value as the first major works that popularised geology as a serious yet accessible science.

Export risk

Throughout his life, Lyell recorded his observations meticulously with frequent cross-references to articles, books, conversations and letters, in a legible hand. Overall, he filled 297 notebooks, of which 294 have now surfaced from his descendant's library. The death of the third Baron Lyell has forced his executors to sell his library's contents in order to pay death duties. Lyell's notebooks have had an offer from an unknown transatlantic individual. The intended purchase faces a temporary export ban to allow time to raise funds to keep the notebooks in the UK. The required sum is £1,444,000.

To fulfil the conditions of the ban, various institutions have agreed to support the University of Edinburgh Library to lead the fund-raising and to provide the home for the notebooks. They would join the largest collection of Lyell material from a an early twentieth century bequest. Importantly, the University of Edinburgh Library would make the notebooks digitally available to the public.

Securing this important resource for the public and academics to research would advance our knowledge of our subject and one of its great thinkers. Studying the history of geology provides a means to connect with 'how we know what we know', intellectually and from past field observations. It can only be achieved if original material, such as Lyell's notebooks, are archived and made available. In the uncertain scenario of an anonymous buyer, the way forward is to secure them for a reliable institution committed to making them accessible.

Crowd-sourcing

Major donations from benevolent individuals, charities, corporations and institutions have been secured. However, their generosity does not amount to the full sum needed. A public fund-raising campaign has been launched to secure the remaining amount. The success of this initiative relies on smaller groups and societies giving what they can and for individuals to respond wholeheartedly to the crowd-sourcing website (**www.ed.ac.uk/giving/save-lyell-notebooks**). Please, if you can, dig deep!

John Henry (FGS); e-mail: john@geolmaps.com

1 The Darwin Project: https://www.darwinproject.ac.uk/charles-lyell (accessed 18/05/19).

2 Baldwin, S.A. (2013) A Brief Bibliography of Sir Charles Lyell, FRS, Bt, geologist. Baldwin's Scientific Books, Witham, 31 pp.

SOAPBOX CALLING!

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

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

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

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

"SECURING THIS IMPORTANT RESOURCE FOR THE PUBLIC AND ACADEMICS TO RESEARCH WOULD ADVANCE OUR KNOWLEDGE OF OUR SUBJECT AND ONE OF ITS GREAT THINKERS"
JOHN HENRY

WINE, WHISKY AND BEER – AND GEOLOGY?

Many laud the influence of rock type on wine and whisky, but **Alex Maltman** highlights the unsung connections between geology and beer

You might be puzzling about what geology has to do with these alcoholic beverages. And certainly, if you're a beer drinker it's unlikely that you will have come across much mention of geology affecting your drink, though whisky lovers may have read of an influence of bedrock on the distilleries' water supply. On the other hand, wine enthusiasts will be well aware of the importance that some attach to vineyard geology, even to the extent of claiming that individual rocks and minerals can be tasted in wine. However, the scientific evidence on all this gives a much more complex picture. In this article, I will suggest that while vineyard geology can affect how well grape vines perform, its effect on wine is over-hyped and its role in whisky is nuanced, at best. With beer, in contrast, geology has a clear relevance, certainly in brewing history, but one that is usually overlooked.

Wine and geology

Vineyard geology has long been held as important, with many a wine being named after something geological. But today such ideas have reached unprecedented heights. There are consortia of producers in highly diverse places claiming a commonality of their wines simply because their vineyards have the same bedrock. There are books urging drinkers to select wines by rock type; there are restaurants with wine lists organised by geology: alluvial wines, volcanic wines, granite wines, limestone wines and so on. Yet none of these claims indicate what the geology actually does or how a particular rock brings something

Fig 1: Chablis, northern France, looking southwest. The finest vineyards are in the foreground, on the best-drained parts of moderately inclined slopes which face southwest, thus maximising exposure to the warmest sunshine. Vineyards in the background produce lesser wines; the most ordinary wines come from the exposed and windy highest parts of the foreground slope, behind the viewpoint

special to the wine in your glass, and our present scientific understanding makes it difficult to see how this might happen.

Geology determines the vineyard landscape (Fig. 1) and soil properties, and hence indirectly affects vine growth. But its main influence concerns water availability to the plant roots. All vines need good drainage, though this can be provided by various soils, for example, the gravels in Bordeaux, chalk in Champagne and the slate scree in Germany's Moselle valley. But vine roots also need access to moisture during dry periods, perhaps through the presence of clay. In practice, however, the physical factors affecting vine growth are commonly manipulated: soils are modified and highly sophisticated irrigation technologies provide a precise water supply to a vine, effectively over-riding the natural geology.

Much of the journalistic and advertising prose that enthuses about geology and wine implies that (unspecified) matter is taken up by the vine roots and then conveyed through the vine to the eventual wine. However, there is a whole series of disconnects between the geochemistry of the vineyard ground and what ends up in your wine glass. For example, the vine attempts to select and balance its uptake of the fourteen or so mineral nutrients it requires, irrespective of the bedrock, and any imbalances are routinely checked for by a conscientious grower and corrected as necessary. In any case, in practice year-on-year most of the nutrients come not from the geology, but from the organic humus in the soil (or artificial fertilizer). The ratios of the nutrients change substantially during vinification, such that their proportions in a finished wine bear only an indirect and distant relationship with the geological minerals in the vineyard. Moreover, their concentrations in wine are tiny (a typical wine has only around 0.2% of inorganic matter in total, mostly potassium) and, apart from salt, they lack taste anyway. Certainly, their presence can *indirectly* affect a range of chemical reactions and to influence our taste perceptions, but these are complex and circuitous effects, a long way from vineyard geology being a dominant factor in wine.

An apparent importance for vineyard geology is fostered by our calling on geological words to communicate taste perceptions. For example, a number of "geological smells" arise from the highly aromatic compounds that settle from the air onto exposed ground surfaces: an earthy smell results from a terpene known ▶

Fig 2: Strathisla distillery, the oldest continuously operating distillery in Scotland, trumpets its use of hard water, which originates in Dalradian limestones around the town of Keith. (Image: CC0 Public Domain)

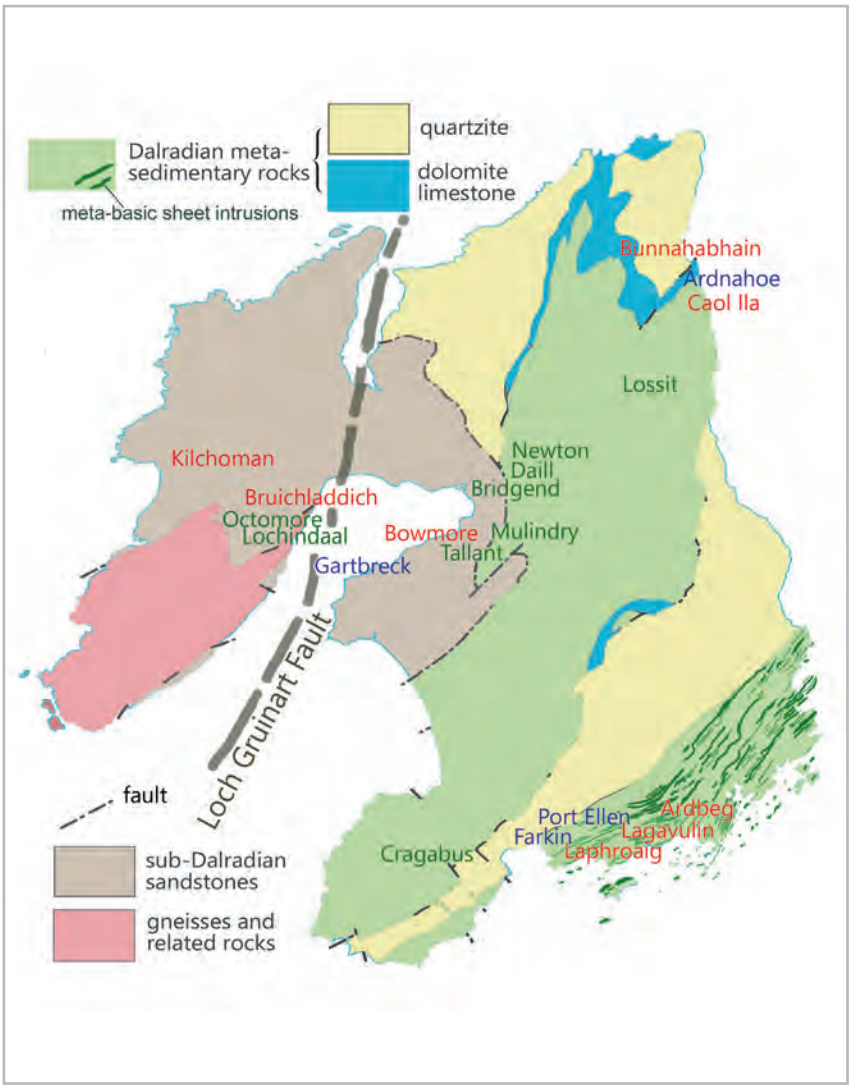


Fig 3: Islay whiskies are said to have a commonality of style, but the negligible influence of geology is apparent from the variety of rocks shown in this simplified geological map. Representative distilleries are shown (former, green; operating, red; planned, blue). Sharp ridges of tough meta-basic sheets have produced a multitude of hidden glens ideal for illicit distilling. (Map adapted from: Maltman, A. The Geology of Wine, Spirits and Beer. Encyclop. Geol. © Elsevier 2020)

as geosmin and the aroma of wet stone is due to the release of various organic oils collectively termed petrichor. Some wines are described as being flinty, presumably through a recollection of the distinctive smell produced by striking lumps of flint together (which involves volatilizing sulphur impurities at the flint surface). Thus, terms like these are being used as mental associations, metaphors: vineyard geology cannot—in any direct, literal way—be tasted in wine.

Whisky and geology

Marketing of Scotch whisky often lauds the virtues of soft water and frequently mentions granite, a rock commonly associated in the public eye with the Scottish Highlands. Certainly, an image of crystal waters tumbling down granite mountains makes good advertising copy. In reality, however, few distilleries use water that has been in contact with granite. Fettercairn, Aberlour, Arran and Glenfiddich are exceptions; some, Oban for instance, capitalize on the consistency offered by mains water. In any case, the majority of distilleries in Scotland draw their waters from rivers and lochs, and this surface water will have had little opportunity to interact with bedrock. And during distillation, the water is, of course, lost. (Almost invariably, reduction of the alcoholic strength before bottling utilises de-ionised water and mostly takes place in centralised plants.)

Over half of Scotland's distilleries produce "Speyside" whiskies, and their waters indeed tend to be soft, but mainly through contact with Dalradian schists and quartzites, rather than granite. However, the claim that this softness is the key to the character of Speyside whiskies is contradicted by those distilleries that use fairly hard water, through having had some contact with Dalradian calc-schists and meta-limestones (Fig 2). Examples are Glen Moray, Dailuaine and Cragganmore. Some Speyside distilleries use groundwater, either from springs (Glenlivet) or from wells (Auchroisk, Macallan), and this can be distinctly hard.

The claim is also contradicted by those distilleries at that other pre-eminent area of quality whisky production, the Isle of Islay, being located on the same kinds of

Dalradian meta-sedimentary rocks (Fig. 3), which yield the same ranges of soft and hard water. For example, the celebrated Islay distilleries of Laphroaig, Lagavulin and Ardbeg use soft, surface water that flowed over Dalradian quartzites, whereas Bunnahabhain uses hard water piped directly from springs in Dalradian dolomite. Others of the island's whiskies are regarded as "Islay" in style, but use quite different waters. Bowmore distillery takes its water from the Laggan River, which passes over limestone, dolomite and grey sandstone; Kilchoman and Bruichladdich water traverses Late Proterozoic sandstones.

The range of Campbelltown whiskies come from just three distilleries (Glengyle, Glen Scotia and Springbank) and all three have the same water source, a small loch located on similar Dalradian meta-sedimentary rocks to Speyside and Islay. Some "Highland" whiskies (e.g. Tullibardine, Aberfeldy and Blair Atholl) also involve waters flowing over Dalradian meta-sedimentary bedrock, though most coastal examples utilise rather hard waters. Examples include Clynelish and Brora, both associated with the Jurassic Brora coalfield, and Glenmorangie, Old Pulteney and Orkney's Scapa and Highland Park—all on carbonate-rich Old Red Sandstone.

There are some general correlations between the inorganic content of the water used in distilling and the regional geology, but research has failed to find any links with the sensory qualities of whisky (Wilson, *PhD Thesis* 2008). So as far as the consumer is concerned, it seems that any effect of geology on whisky taste is swamped by other factors, such as the nature and quality of the starting grain, the degree to which it is peated, the architecture of the stills and the distilling methodology, and the nature and duration of the cask ageing.

However, there are other, subtle influences of geology on the Scotch whisky industry. It is no coincidence that Islay, home of the most heavily peated whiskies, has exceptionally thick deposits of peat, accumulated in the extensive, low-lying tracts developed on unusually soft Dalradian schists adjacent to the regionally important Loch Gruinart fault zone (Fig. 3). Also, some long established distilleries have grown from their illicit predecessors, located where the geology gave hidden sites and crafty getaways (Fig. 3).

American whiskey has its heartland in Kentucky and Tennessee, and here, too, special distilling water is claimed, but for a reason opposite to soft water from granite: hardness due to limestone. But, as with Scotch, the extent to which the water itself affects flavour is moot. A whole range of tastes is produced from this hard water, and within the span are whiskeys made elsewhere in the country with distinctly soft water, for instance, Tuthillltown (New York) on Ordovician (Trenton) shale and Westland (Seattle) with Cedar River water from the Cascade volcanics. The water in Kentucky and Tennessee originates in Ordovician limestones, though the distilleries access it differently. For example, Knob Creek and Woodford Reserve (Fig. 4) use spring water, as does Jack Daniel's for its Tennessee whiskey (its location is even called Cave Springs). Maker's Mark draws its water from a spring-fed lake; Heaven Hill, Old Forester and Buffalo Trace use municipal water.

Other factors have contributed to the pre-eminence of Kentucky and Tennessee whiskey, and to some extent geology is among them. The Ordovician ocean in this area yielded more phosphorus than could be used by the flora and fauna of the time, and the excess was precipitated as apatite and phosphorite nodules, common in today's bedrock. These now lead to soils unusually rich in phosphorus, favouring the growth of corn (maize) for distilling (and the famous "blue grass" of the region). It also helps account for ▶

Fig 4: Woodford Reserve Distillery, the oldest distillery in Kentucky. It is constructed of grey, Middle Ordovician Tyrone Limestone though the use of stone as a building material for distilleries is unusual. Although of no known effect on the plant's whiskey, nearby is the 1.5 km wide Versailles impact crater. (Image: CC0 Public Domain)

	Ca	Mg	Na	Cl	CO_3	HCO_3	SO_4
Plzen	10	4	3	4	12	3	4
Dortmund	225	40	60	60	270	220	120
Vienna	200	60	8	12	10	120	125
Munich	76	18	120	2	152	152	10
Edinburgh	110	24	35	45	170	120	<250
London	52	32	86	34	156	104	32
Burton	352	24	54	16	171	320	820
Dublin	118	4	12	19	164	319	54

Fig 5: Typical ionic composition of waters from major brewing centres. Ionic composition in parts per million. Compiled from various sources

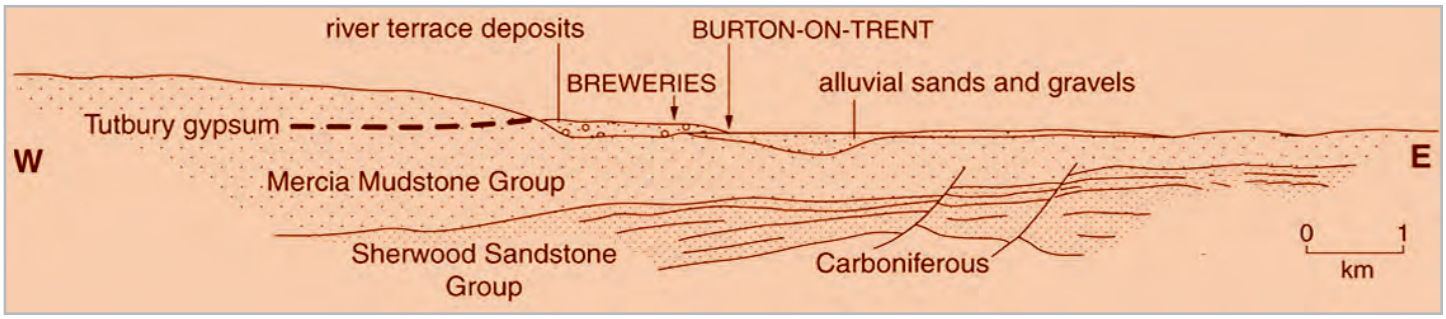


Fig 6: Simplified cross-section of the Burton-on-Trent district, England. Breweries obtain water from both bedrock and surficial deposits, but both are gypsiferous and rich in calcium, magnesium, sulphate and other ions. Brewers elsewhere, including homebrewers, mimic the water by adding "Burton Water salts". (Credit: Maltman, A. The Geology of Wine, Spirits and Beer. Encyclop. Geol. © Elsevier 2020)

the abundant indigenous white oaks here, essential for cask-ageing and the whiskey's distinctive taste.

Beer and geology

Besides water, the primary constituents of beer are cereals and hops—and geology has some influence on both. For example, soils overlying Cretaceous Gault Clay give higher barley yields in dry years than those on Lower Greensand soils, because of their better water retention. Hops, as with grapevines, need free-draining soils with some access to water, such as those derived from Devonian and Triassic sandstones in Herefordshire and Worcestershire, the thick Tertiary molasses of the Hallertau region near Munich, and the volcanic alluvium of the Yakima and Willamette valleys, USA.

It is with water, though, that geology has direct relevance. Historically at least, breweries mainly used well water and, unlike with whisky, that water dominates the finished product. And water chemistry, pivotal to the brewing process (although these days brewers adjust things as appropriate), depends on the aquifer. As a general rule, anions have flavour effects whereas cations affect the brewing: efficient mashing (leaching fermentable sugars from the cereals) is crucial and usually needs a pH within the range of 5.2-5.8.

In the UK, centralised brewing arose at the time of the industrial revolution, and it soon became clear that certain towns consistently delivered a more desirable product. Examples included London, Edinburgh, Masham, Faversham and Carlisle, but no location was to become more famous than Burton-on-Trent. The groundwater at Burton is now universally acknowledged to be ideal for brewing pale ale, or English "bitter". It offers (Fig. 5) an ideal pH and ionic balance, and levels of sulphate that give an unrivalled taste and bite (still known to aficionados as the "Burton snatch", and also found in Dortmund beers). Moreover, all this allowed high hopping rates and hence sufficient stability for the beer to withstand being transported long distances, and even exported—hence "Export Ale", and the journey to India, the birth of today's almost ubiquitous India Pale Ale or IPA.

The key to all this, though little acknowledged in brewing literature, is geology: at Burton, the Sherwood sandstone aquifer is overlain by highly gypsiferous Mercia mudstone (Fig. 6). Similarly, suitable hydrogeological conditions exist at the other early brewery towns. Yorkshire's Tadcaster, for example, has Upper Permian marl containing lenses of gypsum and anhydrite overlying the dolomitic Magnesian Limestone aquifer (Fig. 7), and a water yield enhanced by the several permeable faults.

Simultaneously, on the Continent, new aromatic hops were being introduced, together with so-called "bottom fermenting" yeasts and cool storing of the finished product, a process known in German as "lagering". And, just as in England, one town set the benchmark for this new, clean tasting lager beer—Plzeň in the Czech Republic. In German this town was known as Pilsen and its product, the Pilsener, is a name found today in various forms of spelling on beer labels around the world. This more delicate style of beer is best produced from soft, low mineral content water—just as at Plzeň, located partly on Stephanian (Upper Carboniferous) lacustrine, feldspathic sandstones and partly on Upper Proterozoic metamorphic rocks from which the water was drawn. The latter are intrinsically impermeable, but sufficiently fissured to give some storage capacity. The water at České Budějovice, 150 km to the southeast of Plzeň, is even softer and

Fig 7: The small town of Tadcaster, Yorkshire, made its name with beers using hard, sulphate-rich waters from the NE-dipping Magnesian Limestone (pale blue and dark blue on the map) and overlying gypsum-rich Permian marl. Some Tadcaster beers are affectionally called "Taddy". (Contains British Geological Survey materials © NERC [2019]; Map adapted from Maltman, A. The Geology of Wine, Spirits and Beer. Encyclop. Geol. © Elsevier 2020

Hop field in Germany

drawn from a 300-m-deep artesian well in fractured, older Proterozoic gneisses and migmatites. German speakers know the town as Budweis and its beer as the Budweiser: the original Budweiser beer is still produced there.

But what about those brewing centres with waters that lack the natural balance of the Burton and Plzeň waters? For example, Munich with all its nearby hop fields, chiefly draws its water from Pleistocene fluviatile and glacio-fluvial sands and gravels which, deriving from the nearby calcareous rocks of the Bavarian Alps, have a high carbonate content and high alkalinity that is unsuitable for pale beers. To the rescue, however, come roasted malts. These contain phosphates that are released on mashing as phosphoric acid, which decreases the pH into an acceptable range. It's why Munich became best known for its dark beers. Even the paler lagers produced there today have a richer taste than, say, Pilsners, partly because of the unfermented compounds induced by the relatively hard water.

Vienna waters, although also derived from calcareous rocks in the Alps, are less hard and therefore require a lesser proportion of roasted malt. The result is the characteristic red-amber Viennese lager. Similarly, hard waters in London from the Cretaceous Chalk lead to copper-coloured ales there and, where greater degrees of malt roasting were needed, the historically famous dark ruby porters of the city.

But perhaps the extreme case of using heavily roasted malts is in Dublin, and most famously at the Guinness brewery. The building is sited on bedrock of Carboniferous Limestone and obtains its water from the Blessington reservoir, in the Wicklow Mountains to the west. Although the reservoir itself is located on Silurian meta-sedimentary and volcanic bedrocks, it is fed from limestone-derived gravels that make the water hard. Highly roasted malts lower the mash pH adequately, though the resulting liquor leads to a beer high in tannins, a grainy mouth-feel and the very dark colour characteristic of Dublin or Irish stout, of which Guinness is the most celebrated example. It is one of the world's most distinctive drinks—and essentially because of geology.

So, it is easy to argue that geology has a whole range of influences on beer, both direct and indirect. In other words, of the drinks discussed in this article it is the importance of geology for whisky, and especially for wine, that is most trumpeted—but it is the unsung connection with beer that is the closest.

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Some labels indicating the importance of geology in the world of wine

BUMPS IN THE MED: LANDSCAPE EVOLUTION IN CALABRIA, ITALY

Flat marine terraces clearly viewed from Scilla town with stunning triangular facets above the Santa Eufemia fault trace

Carla Pont investigates the tectonic and lithological controls on river profiles in the rapidly evolving Calabrian landscape

Much of Calabria would not win any architectural prizes. Concrete buildings, protruding steel rods and unfinished exteriors abound due, in part, to the seismic hazards that plague the rugged, craggy toe of Italy's 'boot'. Numerous buildings were destroyed by the 1908 Messina earthquake and tsunami—just one of many that has affected the region in the last few hundred years. This devastating earthquake, measuring 7.1 on the moment magnitude scale, killed up to 100,000 people.

Calabria is tectonically active because it sits above a subduction zone that dips steeply to the northwest, demarking the colliding African and Eurasian plates. Around 30 million years ago, the subducted Ionian lithosphere rolled back in the mantle below causing the Calabrian Arc to form and creating the Tyrrhenian Basin as the crust was extended to the northwest of the subduction zone (D'Agostino *et al., Geophys. J. Int.* 2001). A series of normal faults striking NE-SW accommodate much of the crustal stretching in the area. Landing into Reggio Calabria, you can't help but notice a series of striking flat terraces that outcrop on the Aspromonte Massif at elevations of up to 1 km. Driving across these features, it becomes clear that they are composed of sandy deposits and wave-cut platforms the once lay at sea level. These marine terraces are Pleistocene in age, around a million years old, suggesting very fast uplift rates of 1 mm/yr (Roda-Boluda & Whittaker, *J. Geol. Soc.* 2018).

To outside observers, recent efforts to upgrade the region's road infrastructure have gone ahead regardless of the serious seismic hazards associated with this rapidly shifting landscape, though presumably these risks were considered. To create the newly built A2 motorway, connecting Reggio Calabria to Salerno, a series of tunnels were blasted straight through the uplifting footwall of the Santa Eufemia fault system, which ruptured in the catastrophic 1783 earthquake. Linking these tunnels is a spectacular 220 m strut frame bridge floating above the Favazzina River. The geomorphology of this river records the tectonic history of the Santa Eufemia Fault, and is one of three rivers that I used to gain clues into how this landscape is evolving.

Clues in the landscape

Plate tectonics, like many geological processes, cannot be directly observed. Instead, we must use measurements of Earth's magnetic, gravitational and seismic signals to gain insights, or we can gather clues from the landscape.

Next time you gaze across a landscape, view it as the surface expression of two competing vertical motions—uplift versus erosion. I am particularly interested in rivers because they hold vital clues to this delicate balance. A river in equilibrium with uplift and erosion will have a smooth concave-up profile. However, an established body of literature now shows that river profiles will develop prominent bumps—convexities in the long profile called 'knickpoints'—where the river steepens in response to a change in tectonics, climate or lithology (Rosenbloom & Anderson, *J. Geophys. Res.* 1994; Stock & Montgomery, *J. Geophys. Res.* 1999; Sklar & Dietrich, *Geology* 2001; Roberts & White, *J. Geophys. Res.* 2010; and others). It is therefore possible to use knickpoints to model uplift histories with the stream-power erosion model, which relates erosion to upstream drainage and bedrock erodability.

Knickpoints incise through bedrock, migrating upstream as an 'erosional wave'. However, the controls on the speed of knickpoint migration are poorly understood. For example, recent studies have shown that rivers crossing active faults in the Central Apennines, Italy and the Hatay Graben, Turkey respond much more slowly to tectonics than rivers in ▶

Erosion in action after two days of rains on the sandy marine terraces

Victoria Fernandes testing our river crossing – verdict: barely holding on

the Gediz Graben, Turkey (Whittaker & Boulton, *J. Geophys. Res.* 2012; Kent *et al., Earth Surf. Proc. Landforms* 2017). However, the speed of knickpoint migration doesn't clearly correlate with differences in fault slip rates.

So, the aim of our expedition to Calabria was to gain a better understanding of landscape response times to tectonic forcing driven by active faults, and specifically to explore whether lithology or hydraulic geometry served as better explanations for knickpoint migration speeds than fault slip rates.

Diverse waterways

The trip proved to be exciting and thought-provoking. Calabria is a young, rapidly uplifting landscape, with numerous examples of rivers crossing active normal faults and excellent age constraints on uplift and fault-slip rates. Our small team comprised of myself, Alex Whittaker and Victoria Fernandes from Imperial College London. Over a period of two weeks, we collected rock-strength data and hydraulic measurements along three key rivers in Calabria, the Sciarapotamo, Favazzina and Valanidi rivers, which cross the Cittanova, Santa Eufemia and Armo faults, respectively. Alex had been to Calabria many times, so was an enormous help in contextualising the project. Our working hypothesis was that rivers would incise quickly into rocks with low bedrock strength, while knickpoints in steepened reaches of the river form where rocks had higher compressive strength.

We arrived in Calabria with our shortlist of three rivers to investigate. We spent the first two days on reconnaissance. A wealth of information can be gathered from satellite imagery, but we quickly discovered that some access paths to the rivers were an artefact of agricultural design or, more often, had simply been washed away by landslides. While the mountains of Southern Calabria rise to over 1,450 m, taking a drive along the winding, high-mountain SP3 road made it abundantly clear that this landscape was crumbling fast. Metamorphic basement rocks were strewn across paths; landslides were clearly the norm in Calabria. First impressions suggested that we were dealing with incredibly weak, fractured rocks.

The three bedrock rivers we chose couldn't have been more different. The Sciarapotamo River, overshadowed by

1-km-long viaduct, sat in a broad valley incising into granites. The Favazzina River, lying in a verdant v-shaped gneiss valley, was by far my favourite. Located close to the fishing town of Scilla, where we based ourselves, the river could only be accessed by long walk-ins from the flights of flat marine terraces forming the high topography. Farther south, the Valanidi River exposed calcarenites in the hanging wall of the Armo Fault with some beautiful deltaic sequences.

Highly urbanised and with minimal flowing water, it was difficult to imagine that devastating floods in the 1950s had destroyed towns along the Valandi Valley. 'Fiumara' is the local name for rivers in Calabria, meaning seasonal streams. These rivers are characterised by an ephemeral and torrential regime—in good times, benign, but after a severe rainy period, sudden and catastrophic floods quickly occur. Contrary to visions of hot Mediterranean summers, a few days into the trip torrential thunderstorms made working along riverbeds very difficult. It turns out that Calabria is one of the rainiest regions in southern Italy, with annual rainfall exceeding 1050 mm/yr. Our trusted Fiat Panda could navigate Calabria's steep narrow roads, but was halted when sandy off-road paths were washed away.

Despite inclement conditions, we collected extensive field data at 46 different localities. We gauged rock strength using the concrete industry's instrument of choice, the Schmidt Hammer. We made careful observations of the rock's fracture network and weathering state to quantify bedrock erodability. We measured river geometries using a laser range finder, from which we could later reconstruct stream power and flow velocities relative to the location of the fault. The aim was to gather enough data to understand what measures of rock strength were most important for erosional processes controlling landscape response times.

Complex controls

Some interesting conclusions came out of my initial field data. It seems that rock strength does not correlate with slope or channel width. So, if lithology doesn't control knickpoint formation in these Calabrian examples, knickpoints may instead reflect the temporal and spatial pattern of tectonic uplift, driven by active normal faults. Further analysis of data recording fracture orientation and spacing may improve our understanding of whether alternative measures of rock strength are important for bedrock erosion processes that control landscape response times.

Fieldwork in Calabria was an incredibly rewarding scientific endeavour. As a small team, we constantly debated ideas, attempting to decipher the mysteries of the Calabrian landscapes. Forked lightning, stuck cars and mosquito bites too numerous to count did little to dampen our spirits. Mt Etna formed a majestic backdrop through mists of the Messina straits, while my favourite view had to be that from Scilla's castle walls, where we stood watching the sunset behind Stromboli.

Carla Pont is a PhD student at Imperial College London and was a 2018 recipient of the Geological Society of London's Elspeth Matthews Fund

ACKNOWLEDGEMENTS

I am extremely grateful to the Geological Society of London's Elspeth Matthews Fund for supporting this expedition to Calabria

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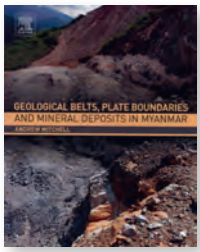
(Full references are listed online)

River re-incising into landslide debris on the Favazzina River

Geological Belts, Plate Boundaries, and Mineral Deposits in Myanmar



Myanmar's geology is like a precious mineral jigsaw puzzle that has been scrunched together after completion. A few tantalising sections of structure are still joined and recognisable, smashed up with isolated pieces. Andrew Mitchell is a geologist with a lifetime of patient field work, half of which has been devoted to his professional focus on Myanmar. Consequently, few other guides could pick through this country's geological jumble with such diligence to explain its stratigraphic sequences.

Broadly, Mitchell splits the country into two parts in his book, one east and one west of the Sagaing Fault. His encyclopaedic knowledge and description of complex sequences and mineral deposits across this difficult and varied region are at odds with the few regions left blank due to inaccessible terrain, which have little or no geological maps, so here Mitchell broadly infers the structure.

Mitchell's unique purpose is to detail the stratigraphy and field geology of Myanmar, thoroughly, in one book. He touches on contextual history, production figures and economic colour to illustrate the country's considerable global resources or geoheritage. The Wa State's mining of huge tin deposits in 2016, which temporarily tilted the axis of the global tin market, and Myanmar's possession of the 'critical metal' antimony, of which it is the second largest producer, is briefly considered within some areas of mineral potential.

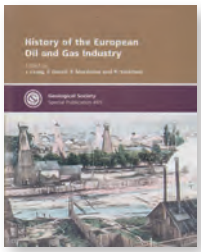
Other than field observations, Mitchell cites an extensive literature dating back many decades, including his own writing and collaborations and many unpublished sources. Throughout the book, Mitchell tends to summarise formation episodes rather than describing a full deposit geology, so a gemmologist like myself would notice that Mitchell does not include the latest literature for his comments on 'current views' on the genesis of ruby and sapphire (Chapt. 7; Mogok Metamorphic Belt). This is understandable given the broad sweep and ambition of the book as a whole.

The book is well illustrated: field photographs are relevant and helpful, and there are many clear, illustrative, colour schematics and maps.

Reviewed by: ***Jessica Cadzow-Collins***

GEOLOGICAL BELTS, PLATE BOUNDARIES, AND MINERAL DEPOSITS IN MYANMAR
by Andrew Mitchell, 2018. Published by: Elsevier
524pp. pbk. ISBN: 978-0-12-803382-1
List Price: £118.00. W: https://www.elsevier.com/books/geological-belts-plate-boundaries-and-mineral-deposits-in-myanmar/mitchell/978-0-12-803382-1

History of the European Oil and Gas Industry



This fascinating volume is the outcome of a meeting jointly convened by the Geological Society's Petroleum and History of Geology Groups, together with the Petroleum History Institute of North America. It offers an insightful set of papers with a mix of technical, commercial and regional perspectives complemented by a fascinating biographically focussed final section on some of Europe's early petroleum geologists whose work has influenced and shaped the upstream industry.

Jonathan Craig and his editorial team should be congratulated on putting together a diverse set of papers that offer an insight into the history of this important aspect of our industrial heritage. It is a weighty tome of almost 500 pages. Some papers are a little dense and whilst being well written and readable, could have been improved using more illustrations and photographs to illustrate key points. The editors opening paper offers an excellent overview and summary, as well as an introduction to the volume. Knowing a little about the UK and North Sea, I found the early papers well written and informative. They also serve to remind the reader of the influence and impact that James 'Parafin' Young had on the wider industry beyond the UK. I was a little disappointed that the Netherlands Groningen Field receives little mention, given its significance and role in opening the Southern Gas Basin and through that, the rest of the North Sea.

The papers on the Italian oil and gas industry are standouts, being easy to read, interesting and well-illustrated. The quality of these and their illustrations, draws further attention to a sense that in some other papers more could have been made by accessing extensive illustrations, photographs and figures held in corporate and other archives; this would have, in my opinion, added further to the volume. One offer that I think would have enhanced the publication is an overview of the history and evolution of the North Sea basin, particularly if offered from a technology perspective, given that this has been one of the most significant and influential hydrocarbon provinces of the late twentieth century to recent years.

Overall this is an excellent volume, particularly for those of us interested in the history and evolution of an industry that has so much shaped and influenced our lives and society. It offers excellent insight and is an informative read that I recommend. It is good to see the Geological Society putting together such a special publication.

Reviewed by: ***Mike Bowman***

HISTORY OF THE EUROPEAN OIL AND GAS INDUSTRY
by J. Craig, F. Gerali, F. MacAulay & R. Sorkhabi (eds) 2018. Published by The Geological Society of London, SP 465, 472 pp. (hbk.) ISBN: 978-1-78620-363-2
List Price: £125.00 Fellow's Price: £62.50
W: www.geolsoc.org.uk/sp465

The First Global Integrated Marine Assessment: World Ocean Assessment 1

This weighty tome includes an extraordinary range of information about almost every major aspect of our marine world. It has been written with contributions from over 600 scientists, and every chapter includes a comprehensive reference list. The depth of information is, necessarily, limited but it is a very useful reference for students and anyone who has

an interest in the global trends affecting our marine environment.

The book is divided into four main sections: (1) ecosystem services; (2) food security and food safety; (3) human impacts on the marine environment; and (4) marine species diversity and habitats with a focus on those identified as threatened, declining or in need of special attention or protection.

It is written in a very readable style and there are some interesting sections for geologists to read. The chapter on calcium carbonate production should be of interest to students studying coastal geomorphology and the potential impacts of climate change on our beaches and islands. The vulnerability of our global communications to geological phenomena are highlighted in the section on cables and pipelines. Who knew that in 2006 a 330-km-long turbidity slide triggered by an earthquake near China caused 19 breaks in seven cable systems? These cables carried a significant proportion of the internet connections for China, Japan and other regional states, meaning a major interruption to economic activities for around 6 weeks.

The chapters on species are not devoid of geological interest, one of the more intriguing is devoted to hydrothermal vents and cold seeps. Both geological settings constitute energy hotspots on the seafloor that sustain some of the most unusual ecosystems on Earth. The diversity of species associated with these geological phenomena is poorly documented, the habitats are characterised as chemosynthetic ecosystems with numerous endemic species living at the sites.

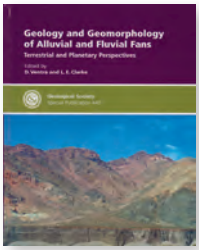
Some sections have little direct relevance for geologists, but are interesting nonetheless because they draw together information on subjects you may never see in your normal day-to-day work (such as fisheries, shipping and sources of hazardous substances affecting the marine environment amongst others).

I would love to keep my review copy, but have reluctantly passed it onto my son, after all he is a marine biologist.

Reviewed by: ***James Montgomery***

THE FIRST GLOBAL INTEGRATED MARINE ASSESSMENT: WORLD OCEAN ASSESSMENT 1
by United Nations Group of Experts of the Regular Process (Lorna Inniss and Alan Simcock (Joint Coordinators)). 2016. Cambridge University Press, 973pp. (hbk). ISBN 978-1-316-51001-8.
LIST PRICE: £120.00 W: www.cambridge.org

Geology and Geomorphology of Alluvial and Fluvial Fans: Terrestrial and Planetary Perspectives



The volume is made up of 16 papers divided into three sections. The first section is, in part, an introduction to alluvial and fluvial fans, the second part is a report on the progress on studying the fans, while the third part discusses potential areas for further research. The other two sections of the volume are on alluvial and fluvial fans. Each paper is written to be able to stand alone.

The volume presents a clear distinction between alluvial and fluvial fans. The definitions and descriptions of the geologic and geomorphic differences between the fan types establishes a common ground for discussion in the volume and is helpful for workers at all levels of competency. Several papers show the relationships between sediment sources and channels near the fan head, as well as changes in either local geomorphology or climate. However, none of the papers address the changes in fan characteristics with respect to strike-slip faulting along a range front and the lateral defection of fans as a mapping tool. Many faults along mountain fronts are highlighted by offset drainages in fans; however, this basic tool is not discussed.

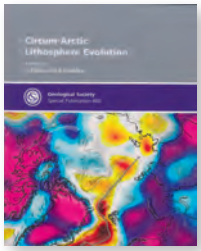
The value of the volume could be increased by adding papers covering topics such as the hazards of building on or the development of water resources within fans, as well as concerns regarding mining fans for building materials. In addition, the volume contains only one paper on alluvial and fluvial features on Titan. This deficiency suggests that the number of planetary papers should have been increased in the volume or that the Titan paper should have been contained in a sister volume.

Overall, the volume is a helpful general resource for descriptions of mainly terrestrial alluvial and fluvial fans. I found the volume useful, especially after reading it a second time. I recommend the volume for persons who are not all that familiar with describing and understanding the growth and general features found in many alluvial and fluvial fans, and as a secondary resource reference for classes in geomorphology and sedimentary geology.

Reviewed by: ***Robert Anderson***

GEOLOGY AND GEOMORPHOLOGY OF ALLUVIAL AND FLUVIAL FANS: TERRESTRIAL AND PLANETARY PERSPECTIVES
by D. Ventra & L.E. Clarke (eds) 2018. Published by The Geological Society of London, SP 440, ISBN: 978-1-78620-267-3 **List Price: £ 100.00 Fellow's Price: £50.00 W: https://www.geolsoc.org.uk/SP440**

Circum-Arctic Lithosphere Evolution



The Special Publication Circum-Arctic Lithosphere Evolution delivers the state-of-the-art for circum-Arctic tectonics and lithosphere evolution. This publication is the place to understand the evolution of the lithosphere north of 66°N; it is the result of the Circum-Arctic Lithosphere Evolution (CALE) project.

Introducing the Arctic Ocean basins, we learn that the Ameriasia and Eurasia basins underly its frozen waters. It is in the description of these basins that we appreciate the relative sparsity of knowledge, irrespective of the recent focus on energy reserves and political demarcation, with regards to the morphology and thickness of sediments.

This volume summarizes the findings of the CALE project, with the aim of bringing together the onshore and offshore geology to better understand the lithospheric evolution of the region and, more specifically, to develop a self-consistent set of constraints for the opening of the Amerasia Basin. These findings are presented in a geographic structure taking the reader around the Arctic by region (including Greenland & Arctic Canada, Alaska & Chukotka, the Laptev Sea, Siberia, Barents & Kara Sea) and finishing on the larger scale with pan-Arctic themes and further research ideas.

These individual papers synthesise both published and new data that make a significant contribution to the regional ▶

geology of the Arctic. Interestingly, onshore studies of Arctic islands, including Wrangel and New Siberian Islands, has shed light on the relationship between the lithospheric history of the area.

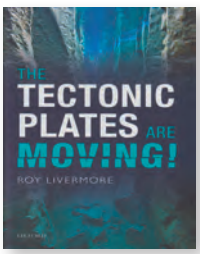
This publication contributes to the dating of the Lomonosov ridge—that unmistakable ridge visible on a bathymetric map of the Arctic Ocean, north of Greenland. It is discussed how the Lomonosov ridge is a slice of continental crust dividing the Eurasia and Ameriasia plates, where a sample-gathering expedition took place to analyse the sediments found therein. The analysis and their implications are discussed and indicate that the ridge was part of a major Mid-Ordovician orogenic event whilst forming part of the Caledonian belt. This paper provides a significant leap forward in the understanding of the tectonic evolution of the Arctic Ocean.

The papers in this Special Publication are the forefront in our knowledge of Arctic tectonics and lithospheric evolution. The lithospheric structure and surface geology in most areas of the Arctic remain poorly defined and are therefore open for significant debate and plenty of exploratory science. The results of this project are necessary to complete our understanding of global tectonics by developing a consistent set of constraints on the opening of the Ameriasia basin.

Reviewed by: ***Simon Kettle***

CIRCUM-ARCTIC LITHOSPHERE EVOLUTION
by V. Pease & B. Coakley (eds) 2018. Published by The Geological Society of London, SP 460, 476 pp. (hbk.)
ISBN: 9781786203236
List Price: £ 110.00 Fellow's Price: £ 55.00 W: www.geolsoc.org.uk/SP460

The Tectonic Plates are Moving!



In 1963, Vine & Matthews published a short paper that brought together magnetic reversals and continental drift, thus signifying the birth of plate tectonic theory. Sometimes described as the grand unifying theory of the Earth, its development is a colourful one involving letters on magnetism from the 11th Century, polar exploration, space exploration, one of the biggest oceanic research initiatives ever to exist, endlessly entertaining acronyms, a famous brewery, personal conflict, international conflict and countless colourful characters. Not to mention that striking similarity between the coastlines of Africa and South America.

Livermore is careful to give credit to all of those involved in the discoveries and research associated with tectonics and it is refreshing to see lesser-known scientists given mention. The diversity and sometimes happy-go-lucky nature of these men and women should inspire us all. The first name basis used for some of the key figures gets a little confusing at times, but gives a lighter feel to the text.

Competing hypotheses are discussed in detail, giving insight into the scientific and human processes involved in the development of a major theory, akin to the more widely known story behind evolutionary theory in the 19th Century, but for Earth science. There is certainly a feeling here that the interpretive nature of Earth science gave rise to high drama among competing academics throughout the past 200 years, with careers made and ruined by single key figures.

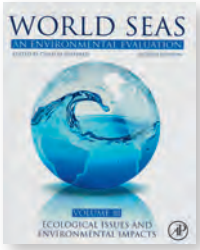
The sheer amount of research behind tectonics conducted over the past century or so is staggering. This is reflected in the book's length: almost 450 pages. However, when the scale of the problem is considered it is quite incredible that we have discovered what we have. The surface of our planet moves in a plate-like fashion over timescales of hundreds of millions of years. We cannot see this directly, so we must rely on the evidence of physicists, geochemists, and geologists. Livermore selects some great photos and figures to illustrate this evidence, reproducing them clearly and in excellent resolution with meaningful captions—not always the case in books of this nature.

Far from being a dense, jargon-laden history book, Livermore brings an accessible writing style and brilliant humour to the story, which certainly had me chuckling. If you know anyone (including yourself!) who is keen to find out more about our planet, give them this book.

Reviewed by: ***Jonathan Scafidi***

THE TECTONIC PLATES ARE MOVING
by Roy Livermore, 2018. Published by: Oxford University Press 490pp (hbk.) ISBN: 9780198717867
List Price: £25.00 W: https://global.oup.com

World Seas— An Environmental Evaluation: Volume III, Ecological Issues and Environmental Impacts



The year 2000 saw the publication of *Seas at the Millennium*, which reviewed the environmental condition of the oceans. Focussing on human interactions with the physical and biological aspects of marine environments, it described methods and techniques that might ensure the continued functioning of aquatic ecosystems.

This present volume is primarily a second edition *Seas at the Millennium*, addressing changes over the last two decades. The environmental story documented is one of continued and relentless decline in marine quality. However, techniques (such as benthic surveys using GPS and satellite photographs) have developed markedly. The topic range being wide (environments, techniques, pollutants), only selected examples more likely to be of interest to geoscientists are highlighted here.

Four chapters describe challenges faced by mangroves, coral reefs, kelp forests and salt marshes—each nurseries for economically-important species. Climate change is a major issue for each. Mangrove forests and salt marshes are being squeezed between human settlements and shifting shorelines as sea level rises. Kelp forests, whose canopies dominate the shallow sublittoral at higher latitudes, need cold winters to reproduce. They are being pushed polewards as temperatures warm.

A chapter on the transport of harmful, invasive species in ballast water suggests that these are also a great anthropogenic threat to the aquatic world. (Such species will be encountered by palaeontologists examining modern environments.) It is recommended that an early warning system be put in place to notify national authorities. Invasive species can also be introduced on floating plastic fragments now stranded on shorelines. Regarding oil spill impacts, knowledge growth has not kept pace with hydrocarbon exploration and production.

Submarine noise, as from seismic

surveys, is a pervasive pollutant impacting cetaceans, fish, invertebrates and larvae. Meanwhile, collisions between ships and cetaceans are largely underestimated events that "can threaten whole populations and even species". Chapters on micro- and macro-plastics document the effects of sedimentation and ingestion, and the impact of ghost fishing from discarded traps and nets.

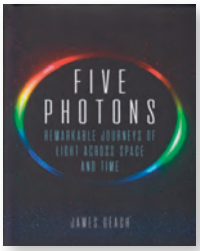
Oxygen-poor Marine Dead Zones in coastal ecosystems are increasing in number and area—as in the Gulf of Mexico. These have arisen from excess inputs of nutrients and organic matter, but from climate change also. Some, such as in the Baltic Sea, are now permanent features.

Thus, there is much here to interest geoscientists working on modern environments. It will be a pity if, this book being so expensive and dense scientifically, it is not also widely read by environmentally-concerned citizens, politicians and corporate leaders.

Reviewed by: ***Brent Wilson***

WORLD SEAS, AN ENVIRONMENTAL EVALUATION, 2nd EDITION: VOLUME III, ECOLOGICAL ISSUES AND ENVIRONMENTAL IMPACTS by Charles Sheppard (ed), 2018, Academic Press (an imprint of Elsevier), 666 pp. ISBN-10: 0128050527, ISBN-13: 978-0128050521 (pbk.)
List Price: £230.00 W: www.elsevier.com

Five Photons: Remarkable Journeys of Light Across Space and Time



The Hitchhiker's Guide to the Galaxy says that "the Universe is an unsettlingly big place". James Geach confirms the truth of that in this book. In doing so he draws a clear and helpful distinction between the observable universe—constrained by the distance light could travel in the time since the universe formed—and its potential actual size, which has no such constraints. The universe is about 14 billion years old, but, when expansion is taken into account, the radius of the observable patch is about 45 billion light years. (It's big and the "excess" accounted for, apparently, by its expansion since the Epoch of Recombination, when light first escaped from the early universe some 380,000 years after the Big Bang, so that the observable distance is significantly greater than that which light could have travelled at its maximum measurable speed.)

The book comprises seven chapters, of which each of the central five is about one of the photons in the title. The opening chapter deals with light in terms of both electromagnetic radiation and particles (photons)—a conceptual duality that is hard to explain and harder to understand. Subsequent chapters cover old light, starlight, dark energy, black holes and long-wave (radio) emissions from the universal dawn. It's all compelling, because the explanations are good—making sense while being relatively simple—and it's where we live. The illustrations (31 of them) are all monochrome and support the text well. Perhaps strangely, for a book about light, this is one of the rare situations where colour would probably be of little, if any help.

Many abstruse issues are involved in understanding the nature and behaviour of light—taken to include the full electromagnetic (or photon) range, from the shortest (most energetic) gamma rays to the longest radio waves—in astrophysics. Geach provides well thought out explanations of many facets and issues. It is hard to see, for instance, how the conventional concept of massless photons can be applied to a system in which the path of light is bent by a gravitational field. The explanations offered extend from baryons and black holes, via Cepheid variables and the cosmic microwave background (CMB), to general relativity and wave-particle duality. Some explanations are more successful than others, but all work, and the book is interesting and relatively easy to read. It is recommended to anyone with an interest in light and/or space/time.

Reviewed by: ***Jeremy Joseph***

FIVE PHOTONS: REMARKABLE JOURNEYS OF LIGHT ACROSS SPACE AND TIME
by James Geach, 2018. Published by: Reaktion Books, London, UK. ISBN: 978-1-78023-991-0. 184 pp. (hbk.)
List Price: £14.95 W: www.reaktionbooks.co.uk

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- **NEW! Metamorphic Geology: Microscale to Mountain Belts**, by S. Ferrero et al. (eds), Geological Society SP 478 2019, 482 pp. hbk.
- **NEW! HP-UHP Metamorphism and Tectonic Evolution of Orogenic Belts**, by L. Zang et al. (eds), Geological Society SP 474 2019, 362 pp. hbk.
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- **NEWLY AVAILABLE! The Role of Women in the History of Geology**, by C.V. Burek & B. Higgs (eds), Geological Society SP 281 2007, 342 pp. hbk. **Re-issued to mark the centenary of female Fellows
- **NEW! Hydromagmatic Processes and Platinum-Group Element Deposits in Layered Intrusions**, by Alan Boudreau, Cambridge University Press 2019, 275 pp. hbk.
- **NEW! Paleozoic Plays of NW Europe**, by A.A. Monaghan et al. (eds), Geological Society SP 471, 398 pp. hbk.
- **NEW! Fluvial Meanders and their Sedimentary Products in the Rock Record**, by Massimiliano Ghinassi et al. (eds), Wiley Blackwell 2019, 592 pp. hbk.
- **Martian Gullies and their Earth Analogues**, by S.J. Conway, J.L. Carrivick, P.A. Carling, T. de Haas and T.N. Harrisin (Eds), GSL SP467 2019, 434 pp. hbk.
- **A Practical Guide to Rock Microstructure (2nd Edition)**, by Ron H. Vernon, Cambridge University Press 2018, 431 pp. hbk.
- **Development of Volcanic Gas Reservoirs: The Theory, Key Technologies and Practice of Hydrocarbon Development**, by Qiquan Ran, Dong Ren & Yongjun Wang, Elsevier (Petroleum Industry Press, Gulf Professional Publishing) 2019, 1066pp. pbk.
- **Volatiles in the Martian Crust,** by Justin Filiberto & Susanne P. Schwenzer (eds) Elsevier 2018, 426 pp. pbk.
- **Plant Flow Measurement and Control Handbook: Fluid, Solid, Slurry and Multiphase Flow,** by Swapan Basu, Elsevier Academic Press 2018, 1288 pp. hbk.
- **Subseismic-scale Reservoir Deformation** by M. Ashton , S.J. Dee & O.P. Wennberg (eds), GSL SP459 2018, 216pp. hbk

It's time to take notice of sand

It's time that sand, as one of our key natural resources, was elevated in our consciousness beyond a local development issue and onto a global natural resource risk register, reports Ian Selby

Our civilisation is built on sand. Little has changed over the past few thousand years and today sand still forms the foundations integral to life, providing us with basic requirements of shelter and infrastructure everywhere in the world. Until the last few years, sand resources have largely been assumed to be infinite and rarely made the news. Now there is a growing recognition that our consumption of sand—perhaps at 20 billion tonnes per year—may not be sustainable everywhere under the present-day supply regime, resulting in some lurid headlines suggesting that across the planet we are running out of sand.

A meeting held in London in January 2019 entitled 'Sand and the Sandbank: is sand extraction a sustainable business?' (https://www.geolsoc.org.uk/GSL-Sand-and-the-sandbank) took a global view of natural sand resources, demand, uses and governance. The underlying question the meeting addressed was: How confident are we that sand, which has always been available in the past, will continue to be readily accessible in the future and be economically and environmentally acceptable to extract? The discussions made it clear that the risks surrounding the sustainable supply of natural sand should be considered globally, while recognising that there is significant variation between countries in the scale and location of the risk and its potential mitigation.

Multi-use

Annual sand usage may be as high as 2 tonnes for each person in the world, making sand the largest anthropogenic material flow on the planet. By far the largest use of natural sand (and the significant volumes of sand made through crushing rock) is as an aggregate in concrete for construction. Sand is mixed with gravel (at a ratio of around 40/60) and cement to make concrete. Particular variations of natural sand are also used in specialist applications including glass production, foundry moulds and proppants.

Marine sands are utilised in 2 main ways – firstly to create land as part of reclamation projects for coastal communities and ports, with volumes for individual schemes sometimes exceeding 200 million tonnes. Examples of large developments include Singapore's port facilities, Chek Lap Kok airport in Hong Kong and Palm Island in Dubai. Secondly marine sand is also essential for beach nourishment, to help create resilient shorelines, because it provides a natural adaptation to climate change on the coast, protecting communities and infrastructure. Whilst annual global volumes pumped ashore currently lie at around 50 million cubic metres, an increase to 500 million cubic metres by 2050 is forecast as the impacts of sea-level changes intensify.

Continued growth

Demand for sand is fuelled by strong underlying trends in population growth, increasing urbanisation, economic growth and climate change, which has resulted in an upsurge in production over the last decade or two. Forecasts suggest these rates of

> HOW CONFIDENT ARE WE THAT SAND, WHICH HAS ALWAYS BEEN AVAILABLE IN THE PAST, WILL CONTINUE TO BE READILY ACCESSIBLE IN THE FUTURE AND BE ECONOMICALLY AND ENVIRONMENTALLY ACCEPTABLE TO EXTRACT?

growth will continue over the next few decades—there will be 3 billion more people in the world by 2100. During this time, centres of population growth will change to include new areas of Asia, central Africa and South America. Concurrently urban population density is decreasing—we need more space, more buildings and more infrastructure.

The growth of China has been remarkable. China poured more concrete between 2011 and 2013 than the USA delivered in the entire last century and, despite slowing rates of growth, China increased its economy by more than the total economy of Australia in 2018, and the world economy will double in size by 2042. The message here is that there are no signals to suggest the demand for sand will fall away in the next few decades. On the contrary, supply will have to significantly increase to support growth projections.

Embrace stewardship

What does this mean for natural sand resources, supplies and the impacts associated with its extraction? Sand is not rare, but there are differences—sand is not all the same. Certain types of sand can only be used for particular applications. The impacts associated with sand extraction are well understood and there are sensitivities around sourcing from certain environments. Clearly, looking ahead sand resources require management intervention as demand grows.

Despite a robust background understanding of the principles, the problem is broad: in most countries we don't really know where sand resources lie, how much sand and what qualities are available and how much is being used. Policies are often absent or immature and associated with weak governance and regulation. In many parts of the world this leads to significant criminality. International trading in sand is limited at present, but growth in value may see an export business emerge.

The ways forward are clear. We must embrace an approach based on stewardship by growing understanding, actively sharing knowledge, and introducing strategic, sustainable resource management practices. Realistically this can only be achieved through the acquisition of reliable data. At the same time, we should explore and understand the scale and character of future demand. Despite press headlines, there isn't a sand crisis. But we do need to take stock now and intervene to manage environmental impacts and avoid a market failure arising from a continued unsustainable development of sand resources.

Ian Selby is in the Sustainable Earth Institute at the University of Plymouth; e-mail: ian.selby@plymouth.ac.uk

DISTANT THUNDER

Behind every good man...

Geologist and science writer Nina Morgan wonders what went on in William Buckland's marriage

As legend has it, it was her intellect that first attracted William Buckland [1784-1956] to Mary Morland [1797-1857]. The two were said to have met on a coach travelling to Dorset when both were carrying copies of Georges Cuvier's latest publication. The title is never specified, but given the timing, it may have been the final volume of Curvier's *Ossemens Fossiles*. Whatever the book, William and Mary fell into conversation—and fell in love. They married on 31 December 1825 at Marcham, Berkshire.

Their coming together was not surprising, given her upbringing. The eldest daughter of a solicitor, Mary's mother died just over a year after Mary's birth. It was her father, who was involved in both canal promotions and coalmines in the Forest of Dean, who may have aroused her early interest in geology. Mary spent much of her childhood living in Oxford with Sir Christopher Pegge [1764-1822], Regius Professor of Anatomy, and his wife, who both admired and encouraged Mary's interest in natural history. Mary was also a skilled artist. She had been sending drawings of *Megalosaurus* to Curvier from 1822 and a year before her marriage had contributed a number of illustrations to William Buckland's publications.

Soon after their wedding, she and Buckland took off on a year-long wedding tour, geologising and meeting other scientists on the Continent. On their return to Oxford, she played an important role in facilitating her husband's rise as a geologist. The Oxford commentator, the Reverend William Tuckwell [1829-1919] describes her as:

"An accomplished mineralogist before their marriage, she threw her whole nature into her husband's work. She deciphered and transcribed his horribly illegible paper, often adding polish to their style; and her skilful fingers illustrated many of his books.... From her came the first suggestion as to the true character of the lias [sic] coprolites. When, at two o'clock in the morning, the idea flashed upon him [Buckland] that the Cheirotherium[sic] footsteps were testudinal, he woke his wife from sleep; she hastened down to make pie crust upon the kitchen table, while he fetched in the tortoise from the garden; and the pair soon saw with joint delight that its impressions on the paste were almost identical with those upon the slabs."

Standing by her man

In 1836, Tuckwell records, when the publication of Buckland's Bridgewater Treatise:

"...roused the heresy-hunters, that a hurricane of private and newspaper protest whistled around his [Buckland's] disregarding head, that Dean Gaisford thanked God on his [Buckland's] departure for Italy – "We shall hear no more of his geology"

Tuckwell notes that Mary prevailed upon her husband to "Keep to the St James' Chronicles, everyone of which has a rap at you; but I beseech you not to lower your dignity by noticing newspaper statements..." suggesting that "Without her moral aid and intellectual support, Buckland would not so lightly and so confidently have faced his difficulties and achieved his aims."

Men only

In spite of all the intellectual power and support Mary contributed to the marriage, Buckland expressed strong opposition to the attendance of women at scientific meetings. In a letter to Roderick Murchison written in 1832, Buckland protested against the idea of admitting women to the second meeting of the British Association:

"I was most anxious to see you talk over the proposed meeting of the British Association at Oxford in June. Everybody whom I spoke to on the subject agreed that, if the meeting is to be of scientific utility, ladies ought not to attend the reading of the papers – especially in a place like Oxford – as it would at once turn the thing into a sort of [Royal Institution] Albemarle-dilettanti-meeting, instead of a serious philosophical union of working men."

Although Buckland doesn't specify to whom the 'Everybody' in his letter refers, his objections to women were not shared by all of his contemporaries. The polymath scientist, philosopher and science historian, William Whewell [1794-1866], organiser of the third BA meeting and the then secretary of the BA, as well as the geologist John Phillips [1800-1874], were just two of the scientists who promoted the idea of 'Ladies tickets'.

Opinions differ

If William didn't appreciate the intellectual powers of women in general—and the achievements of his wife in particular—there were many others who did. Perhaps the highest accolade came from Roderick Murchison—a man notorious for not suffering fools gladly. On 5 July 1854, he wrote to Mary with an exclusive offer:

"If you had been in town, it was my intention to have begged your acceptance of my 'Siluria' ... You will be the *only* [ital sic] lady to whom a copy is sent, and I make this special exception out of sincere regard for yourself and gratitude to your husband, who helped an old soldier to make his way as a geologist.... Ever your sincere friend, Roderick Murchison"

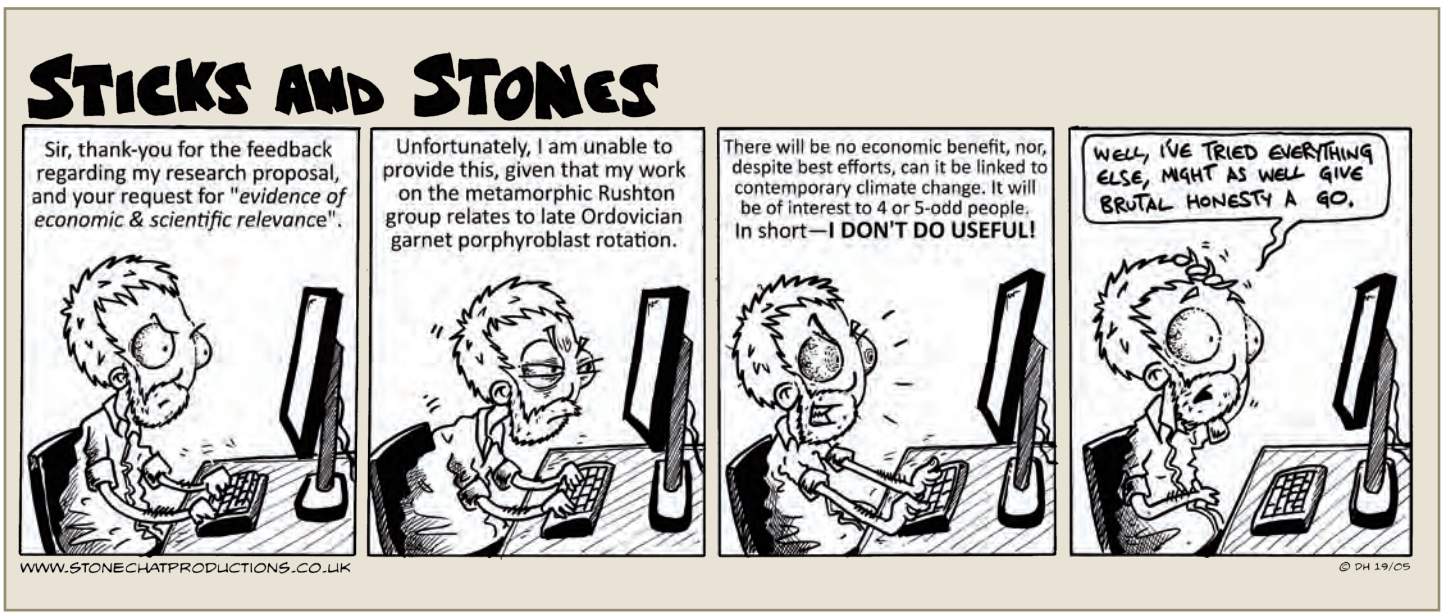
End notes: Acknowledgments and sources listed online

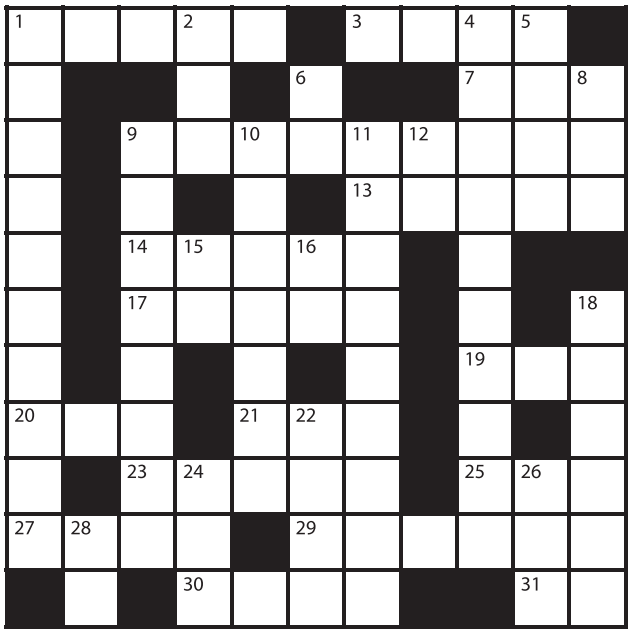
* **Nina Morgan** is a geologist and science writer based near Oxford. Her latest book, *The Geology of Oxford Gravestones*, is available via www.gravestonegeology.uk

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

ENDORSED TRAINING/CPD AND EVENTS

MEETING	DATE	VENUE AND DETAILS
QUIGS workshop: Warm extremes – Marine isotope stage 5e and its relevance to the future	1-4 Jul	Workshop **Venue:** BAS Cambridge, UK **W:** http://www.pages-igbp.org/calendar/2019/127-pages/1910-quigs-wshop-19
ReSToRE Summer School 2019	1-5 Jul	Conference, workshop **Venue:** University College Dublin **W:** www.geolsoc.org.uk/ReSToRE%20Summer%20School%202019
3rd International Congress on Stratigraphy	2-5 Jul	Conference **Venue:** Milan, Italy **W:** http://www.strati2019.it/
27th IUGG General Assembly	8-18 Jul	Conference **Venue:** Montreal, Canada **W:** http://iugg2019montreal.com/index.html
20th INQUA Congress	25-31 Jul	Conference **Venue:** Dublin, Ireland **W:** http://www.inqua2019.org/
Lovelock Centenary	29-31 Jul	Conference **Venue:** Exeter University, Exeter **W:** https://www.geolsoc.org.uk/Lovelock-Centenary-2019
Subsidised Introduction to Micromine Course	5-6 Aug	Endorsed CPD Course **Venue:** Whitefriars Street, London **W:** https://www.geolsoc.org.uk/Micromine%20Intro%20course%20Aug19
Resource Estimation - UK	7-8 Aug	Endorsed CPD Course **Venue:** Whitefriars Street, London **W:** https://www.geolsoc.org.uk/Micromine%20Resource%20estimation%20course%20Aug19





Crossword

Across
1 Northern seam yielding coking coal (5)
3 High carbon deposit found in bogs (4)
7 National Health Service (3)
9 Carboniferous swamp plant (9)
13 Spicy pickle, often with mango (5)
14/18D E.g. Principal strains from a deformation matrix (11)
17 How bats see in the dark (5)
19 A colloquial brew (3)
20 Natural mineral aggregate (3)
21 Technology, Entertainment, Design. As in "---" talk (3)
23 Coal mining city where 74 miners were rescued in March 1812 (5)
25 Type of neutrino (3)
27 Store e.g. for coal or missiles (4)
29 Coal mining county where 195 miners died in May 1928 (6)
30 Headland, Eliot or Loch (4)
31 Element named after the city near the Messel Pit (2)

Down
1 Soft, gassy coal (10)
2 Drink mashed or brewed from dried leaves (3)
4 Hard, high rank coal (10)
5 Daughter of Gaia, mother of Selene (4)
6/28 Qualifier often applied to collieries as in Firbeck ----, Harworth ----, Barnsley ---- (4)
8 Soviet Socialist Republic (3)
9 Colliery noted for its band & where 80 miners died in September 1950 (8)
10 Brown coal (7)
11 Transports used in coal mines (9)
12 Intergrated circuit (2)
15 Most geologically active body in the Solar System? (2)
16 Environment Agency (2)
18 See 14 Across
22 Ingredient of carbonara (4)
24 Charged particle (3)
26 Logic circuit with one output (3)
28 See 6

By Bindweed

Solutions June| Across: 1 desert **6** Arab **9** nan **10** Atacama **13** Wah **14/27** Rub al **16** Atari **19** hoopoe **21** qat **22** pam **25** China **26** Uyo **27** AAAS **29** Kalahari **Down: 1** dune **2** San **3** Er **4** RAAF **5** TBT **7** Sahara **8** Namib **11** a way **12** cat **15** Utopia **17** chica **18** soma **20** pan **23** draa **24** Gobi **26** USA **28** A-h

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OBITUARY James Bruce Blanche (1946-2018)

James Bruce Blanche (QVRM, AE*, BSc, MSc, DIC, FRGS, FGS), known to most as Bruce, was born in Gainsborough. He graduated from Sir John Cass College, University of London with a BSc Hons Geology/Geography and Imperial College with an MSc in Petroleum Geology and a Diploma of Imperial College.

Well known and much liked across the international exploration front, Bruce was an inspirational mentor to numerous colleagues and students, in Scotland, Malaysia and beyond

Malaysia

Bruce's first job was as a geologist with the British Coal Board, Oil and Gas Division (which later became Britoil). In 1977, the division moved headquarters from central London to Glasgow, and Bruce and his family gladly settled in Dunblane. In 1979, Bruce was seconded to the fledgling PETRONAS Carigali and worked as part of a technical team assisting with the training of Malaysian geoscientists and senior management in their endeavour to evaluate and explore open acreage in the Malay Basin. The team made a major gas discovery, which acted as a catalyst for the development of natural gas in the Malay Basin.

Many of Bruce's Malaysian colleagues, who he helped train and mentor, subsequently became senior managers. These good relationships were rekindled many times during his visits to Malaysia as a consultant. Over the years, Bruce continued to promote the hydrocarbon prospectivity of the Malaysian basins.

Scotland and beyond

In 1981, Bruce returned to Britoil's Glasgow offices where he was responsible for assessment of international acquisitions in Northwest Europe, Africa and Latin America.

Following redundancy in 1986, Bruce and his geologist wife Jean started their own hydrocarbon exploration consultancy, based in Dunblane, focussing mainly on North Africa, South Asia, and the Middle and Far East.

From 1998, Bruce held a long-term advisory role with Melrose Resources plc. Melrose was seeking to target basins that had a good G&G data set, recent exploration, by-passed hydrocarbon discoveries that may be appropriate for fast-track development and in countries where the fiscal and legal regimes were moderate and open to negotiation.

Based upon these criteria, the Bulgarian Black Sea was identified as an area of interest. An undeveloped dry gas discovery was identified and Melrose purchased the asset, resulting in the development and production of the Galata gas field and its satellite discoveries, and providing significant cash flow for Melrose. Bruce was instrumental in identifying and evaluating potential several new ventures for Melrose plc and, over later years, he occupied the posts of Exploration and New Ventures Adviser, as well as Country Manager, Egypt and Chairman of the Melrose Companies of Egypt.

Active member

In 2014, Bruce was appointed Honorary Professor in the Institute of Petroleum Engineering School of Energy, Heriot Watt University, Edinburgh where he undertook lecturing of post-graduate students, mentoring and tutorials.

For many years, Bruce was Chair of the Mediterranean, Middle East and Africa Scout Group in London. He was also an active member of the American Association of Petroleum Geologists, the Geological Society of Malaysia, the South East Asia Petroleum Exploration Society and the Petroleum Exploration Society of Great Britain. He was a Fellow of the Royal Geographical Society and the Geological Society of London.

Bruce served in the Royal Auxiliary Air Force. He reached the rank of Squadron Leader and served during the First Gulf War. He was also a military historian.

Bruce died peacefully on 7 November 2018 after a short illness. He leaves a wife, two daughters, a son and three grandchildren. He will be remembered for his extensive knowledge, kindness, humorous stories and ready wit.

➤ Rob Wallace, and a number of Bruce's former colleagues and his family

(This obituary has been edited for brevity. The full, original piece appears online. *Editor*.)

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 Amy Whitchurch at the Society.

OBITUARY Douglas Allenby (1944-2017)

Doug Allenby, a world-renowned mining, tunnelling, and excavation engineer, died in December 2017, aged 73. He was Director of Tunnelling and Chief Tunnelling Engineer at BAM Nuttall (formerly Edmond Nuttall Limited) working for the Company for over 45 years.

Geological fascination

Doug was born in Selby, North Yorkshire, moving to Newcastle-upon-Tyne aged 6, where his father worked as a Civil Engineer. After completing school in Newcastle, he was articled as a pupil under the Port of Tyne Authority Chief Engineer. He completed his ONC there, before working his way through Newcastle University, gaining an Honours Degree in Mining Engineering in 1968.

During this period, he developed his appreciation and fascination with everything Geological, especially related to mining and ground excavations. Lecturers in Applied Geology at Newcastle, Duncan Murchison and Bill Dearman, obviously made an impression on the young student, recalling their unique lecturing and field teaching styles in his later years.

Tunnelling

From 1968 to 1971 he worked on a PhD related to the Second Mersey Tunnel (later called 'Kingsway') and started his long association with The Geological Society, becoming an FGS in 1968. He worked on analysis of stress in tunnel linings, with specific reference to the Second Mersey Tunnel.

On completion of his PhD, he was offered employment with Edmund Nuttall Ltd. and worked on the Channel Tunnel, Phase II, the Foyers Hydro-Electric Pumped Storage Scheme, the Thames Tidal Defences, and an experimental bentonite shield tunnelling project at New Cross in London.

From 1975 he worked on many overseas projects, in Hong Kong, Australia, Portugal and Turkey, supervising Turkish contractors on a six-kilometre sewer tunnel scheme in Istanbul, through hard rock and weak, water-bearing alluvial deposits.

From 1990, as Chief Tunnelling Engineer for Nuttalls, he was involved in many geotechnical and ground engineering projects, including ground treatment, deep well dewatering, shaft sinking and the design of tunnelling equipment. In jacked box applications, he was involved in schemes at Lewisham, Dorney, the M1 Junction 15A and in Boston, USA, then the largest scheme of its type in the world.

Internationally reputed mining and tunnelling engineer, specialist in pipejacking and jacked box tunnelling

Mine reclamation

He also worked on the reclamation of mine workings and spoil-heaps, and remediation work associated with contaminated ground. With BAM Group Company Ritchies, he worked on the Combe Down Stone Mines, and the Grey Gables and Mount Pleasant areas near Bath. This involved deep trench excavations, support and stability monitoring, breaking into disused mines with a 2.4m diameter tunnel, and design of long-term support.

He became a Visiting Professor in Geotechnical Engineering at Newcastle University in 2001, and was a key supporter of the British Tunnelling Society (BTS)-supported MSc Course in Tunnelling Engineering at Warwick University.

He was awarded the Gold Medal from the Institution of Civil Engineers in 2015 and the James Clarke medal from the BTS. He is survived by his widow, June, who has donated these two medals for permanent display at BAM Nuttall's Head Office in Camberley.

By George Reeves

(This obituary has been edited for brevity. The full, original piece appears online. *Editor*.)

The Society notes with sadness the passing of:

Barber, Peter Marriott
Black, John H *
Bradshaw, Reginald
Broecker, Wallace *
Burke, Kevin Charles Anthony *
Butler, Raymond John Thomas *
Clayton, Keith *
Herries-Davies, Gordon L *
Huckerby, John Andrew *
Jobbins, Alan *
Nutt, Michael John Crossley *
Osmaston, Miles *
Rocha, Rogerio *
Simpson, Ian Morven
Simpson, Peter Robert *
Westhead, Robert Keith
Whitham, Andrew Gordon

In the interests of recording 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 amy.whitchurch@geolsoc.org.uk to be commissioned. You can read the guidance for authors at www.geolsoc.org.uk/obituaries. To save yourself unnecessary work, please do not write anything until you have received a commissioning letter.

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

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The Africa E&P Conference 2017 was attended by over 600 delegates, with more than 30 countries represented including Congo, Comoros, Gabon, Guinea, Madagascar, Mozambique, Namibia, Nigeria, Sierra Leone and South Africa. Reflecting the high-quality technical content, 50% of the audience is G&G, with 20% of the audience identifying themselves as C-level executives.

This year the PESGB has received over 90 high quality abstract submissions which will form a diverse and relevant technical programme. Submissions have once again come from across the industry spectrum and include oil companies, service companies and academia. All the main prospective regions of Africa will be considered. We are looking forward to papers on, recent discoveries and forthcoming wells in Africa, including high impact and play-opening wells presented by their Operators. Technical overviews of basins hosting licences rounds will provide a unique opportunity to fast track your technical knowledge ahead of bid deadlines. A range of submissions provide an overview of technical workflows that set the standard for industry best practice. Once again the conference will be the "go to" for Africa E&P activity and in-depth geological understanding of the continent.

60%

of attendees were Presidents / VP / Directors / Exploration Managers / Senior Explorationists / Chief / Senior Geophysicists and Geoscientists

Over 250

companies represented at Africa 2017

29%

of the audience was international with representation from: Comoros, Mozambique, Sierra Leone, South Africa, Namibia, Guinea, Congo, Madagascar, Gabon, Nigeria, São Tomé & Príncipe

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