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The Fellowship Magazine of the Geological Society of London

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Heart of Glass

Fabian Wadsworth on Cordón Caulle volcano, and obsidian's dark secrets

GROUND TRUTH
Gary Nichols on the vital importance of field geology

SMART PHONES...
and the geologist. An Online Special by Tom Dyer

CARBON CAPTURE & STORAGE
A disappointing decision from Government - Online

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Image Entry from 100 Geosites competition
The Cuillin Hills © Gijs de Reijke

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A steam-and-ash plume rises over the ridge from the volcano's vent at dusk

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Opportunity Lost: Stuart Haszeldine laments the Government's decision to scale back on CCS.

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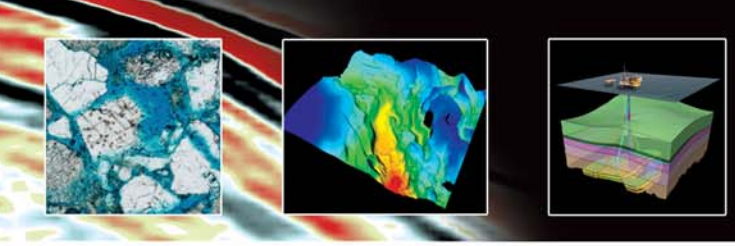

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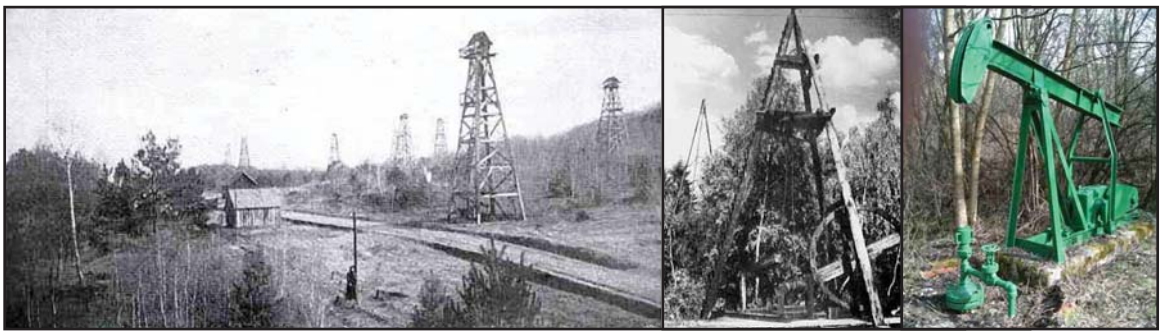
European Oil & Gas Industry History conference

3-4 March 2016

Burlington House, Piccadilly, London



This joint conference between the Petroleum Group of the Geological Society, the History of Geology Group of the Geological Society and the Petroleum History Institute will be held in London in March 2016. It will mark several important anniversaries including 150 years of oil exploration in Poland & Romania, the centenary of the drilling of the first oil well in the UK and 50 years of oil production onshore Spain. The focus of the conference will be to examine the history and heritage of the oil and gas industry in Europe from the earliest onshore drilling (and digging) to its development into the industry that we know today and also to examine the transition from conventional to unconventional resource plays in the onshore arena.

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	UK Shale Gas Exploration - From 1875 to Now
Franco Cazzini:	The Early History of the Oil & Gas Industry in Italy
Piotr Krzwiec:	Birth of Oil Industry in the Northern Carpathians
Jean-Jacques Biteau:	Ayoluengo – 50th anniversary of Spain's only onshore oil field

Associated Events:

A fieldtrip will be arranged over the weekend following the conference to examine the history, industrial archaeology and geology of the UK's earliest oil and gas fields in the east Midlands and the Peak District. During the trip a memorial plaque and information board will be unveiled at the Hardstoft-1 well site in Derbyshire, marking the 100th Anniversary of the drilling of the well under the defense of the Realm Act to reduce Britain's dependence on oil imports.

Tgikuvtcvkqp

To register please visit the conference webpage:
www.geolsoc.org.uk/PG-European-Oil-and-Gas-Industry-History-Conference

For further information please contact:

Laura Griffiths The Geological Society, Burlington House, Piccadilly, London W1J 0BG. T: 020 7432 0980
or email: laura.griffiths@geolsoc.org.uk

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www.geolsoc.org.uk/petroleum

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> TO MOVING THE GOALPOSTS JUST AT THE TIME WHEN A FOUR YEAR COMPETITION IS ABOUT TO CONCLUDE IS AN APPALLING WAY TO DO BUSINESS

Front cover image: © Hugh Tuffen

FROM THE EDITOR'S DESK:

All gas and no gaiters

There was a lot of news around on 25 November – Paris had suffered its bomb attacks on Friday 13, and the aftermath was still filling the bulletins. A Russian jet fighter had been shot down over Turkey. And Mr Osborne, Chancellor of the Exchequer, presented his Autumn Statement. The NHS had a nice surprise: many less so. But nobody noticed a letter entitled 'HM Government Statement to Markets Regarding Carbon Capture and Storage Competition' issued by the Department of Energy and Climate Change, released at 14.57.

It was brief: 'Today, following the Chancellor's Autumn Statement, HM Government confirms that the £1 billion ring-fenced capital budget for the Carbon Capture and Storage (CCS) Competition is no longer available. This decision means that the CCS Competition cannot proceed on its current basis. We will engage closely with the bidders on the implications of this decision for them.' And that was that. The competition had been launched in 2012. This decision to pull the plug came days before the opening ceremonies of the international climate change talks in Paris.

CCS technology (see Policy Update, p. 7) allows CO_2 emissions from large point sources – we're talking power plants here - captured and injected into underground storage reservoirs – typically, old North Sea gasfields. This would enable Britain to continue to use coal and gas-fired power stations while at the same time reducing greenhouse gas emissions. It was said to be crucial to meeting the UK's reduction targets.

Two projects still remained in the running: the Peterhead Project (Aberdeenshire) – where Shell and SSE were planning to fit CC technology to an existing gas generator, and Yorkshire's White Rose Project – a new-build coal-fired power station. Shell immediately announced they saw no future for the Peterhead project 'in the near term'. Backers of White Rose said it was 'difficult to imagine its continuation in the absence of crucial Government support'.

Luke Warren, CEO of the CCS Association, said: "Today's announcement that the funding for CCS will be cut is devastating. Only six months ago the Government's manifesto committed £1 billion of funding for CCS. Moving the goalposts just at the time when a four year competition is about to conclude is an appalling way to do business."

We can only agree. CCS offers a chance to bridge the economy to a low-carbon future and offers hydrocarbon companies the chance to use their expertise in a way that helps them to do the same.

To read more on this, see our second Online Special, this month.

DR TED NIELD, EDITOR - ted.nield@geolsoc.org.uk @TedNield @geoscientistmag

SOCIETY*NEWS*

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

CGeol in the Oil & Gas Sector

Chartership is catching on in the hydrocarbon sector, writes Bill Gaskarth.

The take-up of the Chartered Geologist title from this sector was pioneered by RPS Energy and nine of their senior geoscientists are now CGeols. BG Group has followed closely; to date they have 15 CGeols on the staff, with two more being interviewed in January. I hope that other companies in this sector will follow this lead. The article by Mike Daly (December/January *Geoscientist* 25.11, p06) makes a strong case for others to follow.

Overall interest in CGeol in this sector is growing - and in the last year we have had 26 successful applications. In addition, RPS Energy has had its Training Scheme accredited - as has ERC Equipoise.

Training courses run by Nautilus are now accredited for use in professional development on the way to Chartership, as well as for adding and refreshing skills in later career (CPD). Similarly, Stag Geological has applied for the accreditation of four of their training courses, and hopefully, by the time you read this they will have been accepted.

Geological Society Club

The Geological Society Club, successor to the body that gave birth to the Society in 1807, meets monthly (except over the field season!) at 18.30 for 19.00 in the Athenaeum Club, Pall Mall, or at another venue, to be confirmed nearer the date. Once a year there is also a buffet dinner at Burlington House. New diners are always welcome, especially from among younger Fellows. Dinner costs £57 for a four-course meal, including coffee and port. There is a cash bar for the purchase of aperitifs and wine. Burlington House dinners include wine.

2016 meetings: 2 February, 9 March, 6 April, 11 May.
All will be held at The Athenaeum Club.

Fellows wishing to dine or requesting further information about the Geological Society Club, please email Caroline Seymour on **carolineseymour554@hotmail.com**

LONDON LECTURE SERIES

Highly focused fluid expulsion from sedimentary basins: processes and products

Speaker: Joe Cartwright (Oxford University)
Date: 17th February

Programme

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

Further Information

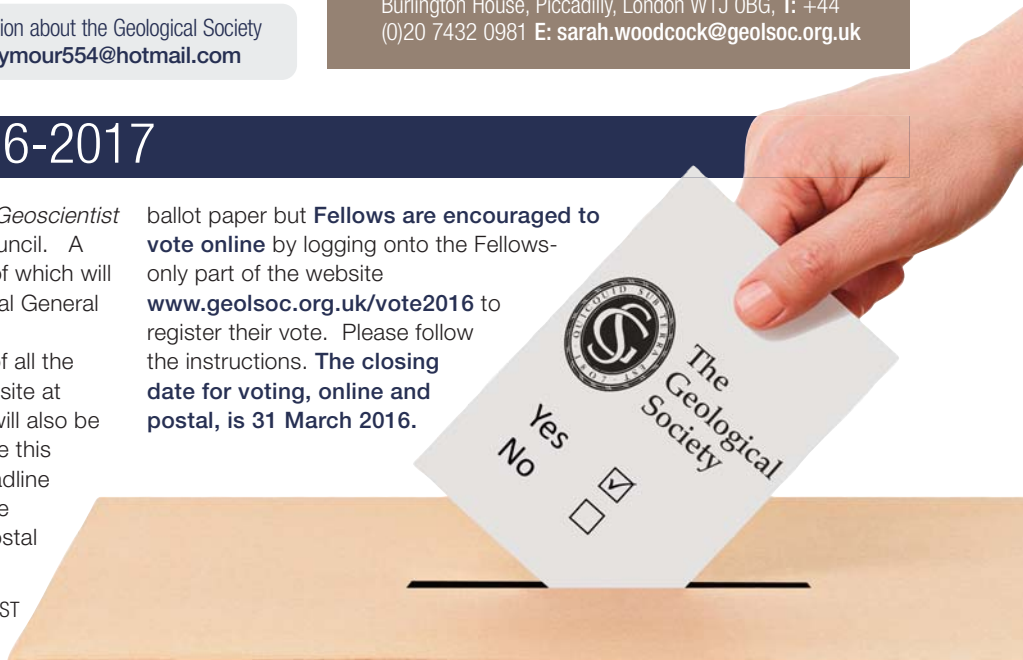
Please visit **www.geolsoc.org.uk/shelllondonlectures16**. Entry to each lecture is by ticket only. To obtain a ticket please contact the Society around four weeks before the talk. Due to the popularity of this lecture series, tickets are allocated in a monthly ballot and cannot be guaranteed.

Contact: **Sarah Woodcock**, The Geological Society, Burlington House, Piccadilly, London W1J 0BG, **T:** +44 (0)20 7432 0981 **E: sarah.woodcock@geolsoc.org.uk**

Elections to Council 2016-2017

Stephanie Jones writes: The October issue of *Geoscientist* invited Fellows to nominate new members of Council. A preliminary ballot will be conducted, the results of which will determine the list for the formal vote at the Annual General Meeting to be held on 8 June 2016.

By the time you receive this issue full details of all the candidates will be available on the Society's website at **www.geolsoc.org.uk/elections2016,** and you will also be able to vote online. It was not possible to include this information with this issue because the copy deadline was before the closing date for nominations. The March issue will include full details including a postal ballot paper but **Fellows are encouraged to vote online** by logging onto the Fellows-only part of the website **www.geolsoc.org.uk/vote2016** to register their vote. Please follow the instructions. **The closing date for voting, online and postal, is 31 March 2016.**



Since the general election, the team has continued to work on aspects of Government policy relevant to the geoscience community

We have also responded to inquiries from Select Committees in both houses of Parliament *writes Flo Bullough*. Over the summer, we provided evidence on how immigration relates to UK science, engineering and skills. We responded to the Home Office Migration Advisory Committee (MAC) call for evidence on the Review of Tier 2, and the Campaign for Science and Engineering (CaSE) survey on immigration - which will inform their work on behalf of the wider science community. We also provided input to a House of Lords Science and Technology Committee inquiry on the relationship between EU membership and UK science.

We responded to the newly appointed Energy and Climate Change Committee's inquiries on 'Priorities for Holding Government to Account' and 'Investor Confidence in the UK Energy Sector'. We raised the importance of consistent policy regarding Carbon Capture and Storage for meeting the UK's decarbonisation targets. We are working with University Geoscience UK on the reform of Geology GCSE and 'A' level, as well as proposed changes to Higher Education funding structures, quality assessment and the proposed Teaching Excellence Framework.

We contributed to the work of the Science Council and CaSE on the Science Budget and the November 2015 comprehensive spending review. We were pleased that the Government committed to protecting the £4.7 billion science budget in real terms up to the end of the parliament. Other announcements included departmental cuts of 22% to DECC, 15% to DEFRA and 17% to BIS and the cancellation of the £1bn CCS demonstration competition.

➤ All Geological Society responses can be found on the policy area of the Society's website: **www.geolsoc.org.uk/consultations**

FUTURE MEETINGS

Dates for meetings of Council and Ordinary General Meetings until April 2016 shall be as follows:

Ordinary General Meetings:
- **2016:** 3 February
- **2016:** 6 April
- **2016:** 18 June

Meetings of Council:
- **2016:** 3 February
- **2016:** 6 April
- **2016:** 18 June

Après Mud, le déluge

After the glories of mud in 2015 we are ready for a whole year devoted to our new theme of Water, writes Flo Bullough.

Throughout 2016, we will be exploring the different and varied ways in which geology and water interact and the importance of these links to people and the environment. The importance of water – as solid, liquid or vapour - to geological processes cannot be overstated. Water is essential to rock-forming processes including sedimentation and dewatering, understanding groundwater, glaciation, ocean chemistry, palaeoclimate, geological hazards– the list goes on! Important links between geology, water development and sustainability also underpin several of the recently announced UN Sustainable Development Goals and discussions at the recent COP 21 summit in Paris.

A key component of the Society's communications work is to improve understanding (among decision-makers, students, and the wider public) of how the subsurface contributes to people's lives. We do this through meetings and lectures, outreach initiatives, education projects and written policy resources. We are highlighting the interconnectedness of geology and water in 2016 through a mini-series within the (London Lectures) on the theme of Water. Topics will include tsunamis, groundwater and water on Mars, as well as a broad overview of this extraordinary substance.

➤ For more on the Year of Water: W: **www.geolsoc.org.uk/water16**

SOCIETY*NEWS...*

Celebrating Hardstoft

Image: Devonshire Mss., Chatsworth, Tibshelf/Hardstoft Oilwell papers

Hardstoft No. 1 well, Tibshelf, Derbyshire

Jonathan Craig hails the forthcoming conference to commemorate the first producing oil well on the British mainland.

The Geological Society will celebrate the Centenary of the Hardstoft Discovery – Britain's first Oil Field – in May 2019. The celebration will start during a special conference next month on 'European Oil & Gas Industry History' at Burlington House (3, 4 March), convened by Petroleum Group, History of Geology Group (HOGG) and the Petroleum History Institute (see p4).

A fieldtrip to the East Midlands Oil Province following the conference will include a visit to the Hardstoft No. 1 well site. Further details are available on the Geological Society website. To coincide with this conference, next month's main Feature article in *Geoscientist* (written by me with co-authors Gluyas, Laing and Schofield) will tell the story of how the UK got its first producing well.

From the Publishing House

Anne Davenport and Jenny Davey bring you the latest news from the Society's Publishing House.

Recently published in GSL journals

- From *Journal of the Geological Society:* The Fezouata fossils of Morocco; an extraordinary record of marine life in the Early Ordovician, by Peter Van Roy, Derek E G Briggs and Robert R Baines
- From *Quarterly Journal of Engineering Geology and Hydrogeology:* Landslide activity in London Clay at Warden Point, Isle of Sheppey, SE England a photographic fea-ture by Derek Maynard and Edward N Bromhead and Sinkhole hazard case histories in Karst terrains by Tony Waltham, this year's Glossop lecturer.
- From *Geochemistry, Exploration, Environment, Analysis:* Evaluation of portable X-ray fluorescence (pXRF) in exploration and mining: Phase 1, control reference materials by Gwendy E M Hall, Graeme F Bonham-Carter and Angelina Buchar .
- From *Petroleum Geoscience:* **The North Falkland Basin revisited:** exploration and appraisal of the Sea Lion Field by L S Williams and R Newbould
- From *Scottish Journal of Geology (published on behalf of the Geological Societies of Edinburgh and Glasgow):* Sauropod dinosaur trackways in a Middle Jurassic lagoon on the Isle of Skye, Scotland by Stephen L Brusatte, Thomas J Challands, Dugald A Ross and Mark Wilkinson. Download this paper free from the Lyell Collection until the end of February!

http://sjg.lyellcollection.org/content/early/2015/11/18/sjg2015-005

Too busy to browse?

Fellows can keep up to date with the latest content published in GSL journals by signing up for free 'table of contents' alerts. Simply go to **http://www.lyellcollection.org/** and click on the link to Email alerts.

Online books for Fellows

Fellows have free online access to the Book Archive – from 2016 access to books published in 2012 and earlier is free online. For a small additional fee Fellows can add the Full Book Collection which extends access to all new and recent books online since 2012. Go to **www.geolsoc.org.uk/fellowsaccess** to make sure you make good use of your Fellowship benefits.

Love hardback?

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Geofacets GSL Millennium Edition

Fellows have exclusive individual access to over 24,000 geological maps from the Lyell Collection in this Millennium edition. To sign up go to 'MyGSL' on the website.

Bookshop Newsletter

If you want to find out more about new books, sign up for our Bookshop Newsletter at **www.geolsoc.org.uk/newslettersignup**.

Warm words are not enough

David Nowell* fears that official and media ignorance and hypocrisy over climate change are in danger of turning him into a curmudgeon…

In March 2015 *The Guardian* launched a climate change campaign, and started tagging many of its features and reports with a 'Keep it in the ground' tag. Such a divisive approach is utterly counterproductive in a society addicted to hydrocarbons, and which needs fresh resources to replace them. Geologists are assumed by many campaigners to be on the 'wrong' side of this debate. Nothing could be further from the truth.

Misleading

Without question, 2°C, or even 1.5°C warming is the most dangerously misleading target humanity has ever – and worryingly complacent, when we have no way of knowing what levels of greenhouse gases will trigger irreversible global heating over the next few hundred thousand years.

The IPCC ignores a wealth of geological evidence, including similar events during the Paleocene-Eocene Thermal Maximum ~56Ma, or the Cenomanian-Turonian ocean anoxic event at ~93.5Ma. We should not flatter ourselves that a mass extinction is required to wipe us out! Pliocene climatic conditions, when we last had similar CO_2 levels, are ignored. Worse still, the nonsensical 40% increase over pre-industrial levels is calculated from zero, rather than from 170ppm during the most intense Quaternary glaciations. Already this rise is greater than during the end of the last ice age over many thousands of years. This would be just as stupid as converting the 0.81°C rise in global atmospheric temperatures (above the 20th Century 15.8°C July average) into degrees Kelvin, which would be only 0.28%!

Rather than interview geologists like Maureen Raymo, the first female Wollaston Medallist who did not even get reported, contributors persistently misunderstand key scientific evidence. Having twigged that Bill McKibben (10 March) had got confused, *Guardian* readers' editor directed me to a paper in *Science*, which confirmed that he had mixed up groundwater depletion across the western United States with California, while uplift in the Sierra Nevada was caused by loss of snowpack. A trivial mistake (over Oxford PPE degrees!) was given a lengthy printed correction on the very next day (26 August), yet a gross geological blunder like this remained uncorrected. If a little knowledge is a dangerous thing, then misplaced expertise will result in fatally ill-informed policies.

Protesting

Protesting about Arctic drilling (to assuage our guilt over driving and flying abroad for too many holidays) won't resolve anything. What about insulating homes? Or campaigning for anaerobic biogas digesters, and against overconsumption (including 'two for the price of one' offers, which also hinder fair price-comparisons)? 'Reduce, Reuse, Recycle' hardly merits a mention, alongside the environmental impact of supposed parental choice in schooling: suburban kids are increasingly driven around, adding greatly to lethal diesel-fuelled congestion, discouraging walking and contributing to obesity in the young.

The Guardian itself could self-sacrificingly ban pointless double-page adverts, always skipped without reading, in favour of quarter-page ones which catch the eye. Why pay more for less impact?

It is wise to remember an old Spanish proverb: 'Take what you want, says God, but pay'.

➤ References for this piece may be found online. Editor

* **David Nowell** is a freelance geologist whose publications include over 120 geological map and book reviews.

SOAPBOX CALLING!

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

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

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

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

> IF A LITTLE KNOWLEDGE IS A DANGEROUS THING, THEN MISPLACED EXPERTISE WILL RESULT IN FATALLY ILL-INFORMED POLICIES
>
> David Nowell

INTO THE VOLCANO

Fabian Wadsworth and **Hugh Tuffen** *

climb into the active crater-source of volcanic glass for the first time, to understand how obsidian forms and flows

***Above:** January 2012. The steam-and-ash plume rises over the ridge from the volcano's vent at dusk*

Obsidian is an enigmatic natural volcanic material that has been used by humans throughout archaeological time *writes Fabian Wadsworth*. It has been used as a precious jewel and a sharp tool, with trade routes extending across continents. Its utility surely derives from the ease with which it can be shaped to purpose while maintaining durability, strength or desirable lustre. It is certainly a material that engenders mystical associations, whether in the form of the *dragonglass* material's ability to shatter White Walkers (in George Martin's *Game of Thrones*) or John Dee's (AD 1527-1608) occult mirror tool (British Museum item M&ME 1966, 10-1,1). Yet despite its long history of use and fascination, the processes by which this volcanic glass forms have only recently received close scientific attention.

Eruption

Volcanic glass is a rare material that can record much of its own history - from before its formation, to its flow behaviour, eruption characteristics, deposition at surface, subsequent cooling, erosion, burial and use by people. As such, each piece of obsidian contains a wealth of information that may span centuries. This 'information richness' draws volcanologists from across the globe to places where obsidian is formed. One such place is Cordón Caulle in Chile.

Before 2008, no obsidian-forming eruption had been witnessed *and* studied. That changed when Chaitén volcano (Chile) erupted violently, forming an obsidian-rich volcanic dome in a large crater. Shortly after, in 2011, not far from Chaitén, Cordón Caulle re-activated and erupted a long tongue of flowing, liquid obsidian[1]. That eruption

> OBSIDIAN CONTAINS A WEALTH OF INFORMATION THAT MAY SPAN CENTURIES. THIS 'INFORMATION RICHNESS' DRAWS VOLCANOLOGISTS FROM ACROSS THE GLOBE

January 2012. The dark black obsidian appears grey when coated with volcanic ash. Jon Castro and Ian Schipper look to the cone and vent from which the obsidian is being squeezed

Left: January 2012. The forested land on the trail to the volcano is smothered in volcanic ash from the eruption

Right: January 2012. The plume is swept over by strong winds as we walk toward the obsidian lava flow front

Centre: January 2012. Some plants survive the ash

Right: January 2012. Close up to the vent. Our unique observations provided evidence that the hot explosions occurred simultaneously with the effusion of obsidian lava. Violent activity and creeping lava flows are, in fact, coincident

continued into 2013, and the obsidian lava remained sufficiently hot to keep flowing for another year, finally halting sometime in 2014.

These two events marked a turning point in our understanding of obsidian-producing volcanoes. The most revealing observation was that obsidian is often slowly pushed out of the volcano's vent as a lava while, simultaneously, large explosions produce huge quantities of volcanic ash (itself tiny shards of volcanic glass). It had been thought that these different eruption styles, violent explosive and more-gentle effusive, were separated in time by a shift in eruption dynamics. Now we know that obsidian is intimately linked to explosions.

In fact, according to the so-called 'Castro-conjecture', all obsidian forms from such explosive events, which are the only way that the thick volcanic magma can lose the excess volatile phases that build up pressure in the system below the surface[2]. This proposition has led to a new view of obsidian-forming eruptions wherein cycles of explosive pulverisation of volcanic glass subsequently heal back into dense glass. It is believed that during this process, all excess gases and volatiles rush out into the atmosphere, carrying with them some of the pulverized shards of volcanic glass in the form of volcanic ash.

So how can magma be pulverized into shards of volcanic glass and then fuse back again into obsidian? Volcanic liquids (magmas) are usually highly viscous when they reach the Earth's surface, due to several factors. First, they have cooled during ascent through the crust; second, they have lost much of the water dissolved in the liquid, and third, crystals may have formed - all of which act to increase viscosity. When liquids become very viscous they can start to exhibit interesting properties.

Viscoelasticity

The most important of these is *viscoelasticity*, a transitional state between liquid-like and solid-like behaviour. When liquids are viscoelastic, rather than simply viscous, they have a propensity to respond to a stress like a glass, rather than like a liquid. In that moment, they can fracture and shatter into small shards. This is known as a *glass transition* phenomenon.

Like most interesting physical processes, this can be thought of as the competition between two timescales. First, the flow (either a lava flow or the flow of liquid through the crust on its way to surface) is moving with a velocity, which is associated with a particular timescale. Second, the liquid ▶

January 2012. At night, a thermal camera highlights the heat of the pyroclasts ejected from the vent

January 2012. The black lava is coated with ash and the far-off vent roars violently. The lava closest to us crackles and creaks like a hot black glacier. The sound of fracturing magma reminds us that liquids in volcanoes can break like solids

January 2015. Years later, when the eruption has stopped, mist veils the obsidian lava from view as we hike around to the vent area ready to descend into the mouth of the volcano

itself takes a particular amount of time to dissipate stresses that build up. This second timescale gets longer as the temperature of the liquid decreases, or if dissolved magmatic water is lost.

One of the simplest, but most powerful volcanological concepts, is this: if the first timescale is much longer than the second, then the magma will behave dominantly as a liquid. If, however, the second timescale is much longer than the first, then the magma can behave as a solid and can shatter. Most hot obsidian-forming liquids arrive at the Earth's surface at temperatures and with velocities which mean that the liquids straddle this viscoelastic *glass transition* and can both flow and fracture in cycles.

Once shattered, however, these still-hot materials can relax back into a liquid-like state. When this happens, an interesting situation arises where a 'granular liquid' exists. A granular liquid that is as sticky as magma will stick back together, or 'heal'. This process of shattering, relaxation and finally healing seems to occur rapidly and repeatedly in obsidian-forming volcanoes. This is how we might find a piece of dense, pure, shiny black volcanic glass at the Earth's surface without knowing that at some depth below, it was shattered and healed over and over again. This is the so-called Castro conjecture, mentioned above and named for Professor Jon Castro (Johannes Gutenberg Universität, Mainz, Germany).

The time required to heal the granular liquids resulting from these fracturing events is the subject of much study at the moment. The times involved in this process are inherently linked to the size of the shattered

particles formed, and the temperature at which they reside inside the volcano. The smaller the particle formed or the hotter the magma, the faster the process. This healing process – called 'viscous sintering' or 'viscous welding' – is critical to understanding how long these shattered fractures can remain open and thus act as channels for gas-escape.

This concept underlies the currently accepted explanation for why these high viscosity magmas explode in huge shattering events, and goes some way towards explaining the textures and observations found at Cordón Caulle volcano. We hope that future models of fracturing and welding cycles will help us to understand how quickly the magma has to de-gas in order to avoid catastrophic explosive eruptions – the result of inefficient outgassing and pressure build-up beneath the Earth's surface.

Collaborative

To this end, between 2012 and 2015 an international collaborative effort by researchers has focused attention on Cordón Caulle. In 2014, this interdisciplinary team camped on the south side of the still-flowing lava and, early one January morning, hiked to the centre of the complex and into the still-active volcanic vent. The vent area was no longer host to explosive eruptions but the ash-laden ground still shook with sub-volcanic seismicity and the gas output from fumaroles still warranted the wearing of breathing equipment. By midday the science team was on the crater floor, walking on the obsidian that had most recently been squeezed out during the effusive eruptions. These deposits of volcanic glass are at the very mouth of a volcano which, only a year before, was exploding violently.

There, they found textures that had not been investigated previously - textures that support the conjecture that all obsidian arises from vigorous explosive pyroclastic activity and subsequent healing. Large fractures in the obsidian lava at the source itself were open and coated in red, oxidised veneers. In detail, under a scanning electron microscope, these surfaces are revealed as coatings of volcanic glass shards frozen in the process of healing to the glassy walls.

These provide us with a snapshot of the explosive part of obsidian's history. While similar features have been seen within older, deeper, now-exposed obsidian features in Iceland[3], this exciting observation at Cordón Caulle volcano allows the first link between observations of the eruption itself with observations of the products preserved shortly after the eruption ceased.

Understanding this process of how these particularly high-viscosity magmas lose their volatiles in a complex combination of explosions and effusive activity, is the key to understanding Earth's most dangerous volcanoes. For example, traditional models of volcanic degassing involve the formation of bubbles. These coalesce in foamy regions and provide permeable pathways for highly pressurised gas to escape – avoiding explosions. However, key work has now changed that view.

Often, bubbles cannot form or grow sufficiently simply because the magma is too viscous. In such cases, the magma may break and shatter instead. Shattered zones may be another way to form permeable channels for dangerously high-pressure gas to escape. However, in this model, gas escapes in a vigorous explosion, rather than without one. That key distinction appears to be congruent with the observations at Cordón Caulle made by the team in 2011-2013.

Volcanologists from the University of Lancaster (UK), Ludwig-Maximilians-Universität (Germany), Johannes Gutenberg Universität (Germany) and Victoria University (New Zealand), with other collaborators worldwide, are working to understand this phenomenon further.

Towards prediction?

Currently, it is not possible to predict a volcanic eruption. However, great strides have been made to understand how this might be achieved in the future. A paradigm shift occurred when seismologists discovered that much of the seismicity they were recording at the Earth's surface around volcanoes was in fact produced in these unseen fracturing and shattering events happening up to a kilometre or more below.

When a shattering event occurs, it produces a large amount of seismic energy which is transmitted through the Earth's crust and recorded by seismometers. Once filtered, volcano-seismologists can track these. If seismicity accelerates, an eruption usually occurs. Recent work has suggested that these obsidian forming eruptions may be inherently less predictable than other eruptions. This work suggests that if the seismicity ▶

Above: January 2015. After rainfall, the lava steams because, at its core, it is still very hot even years after the eruption has apparently stopped

> BY MIDDAY THE SCIENCE TEAM WAS ON THE CRATER FLOOR, WALKING ON THE OBSIDIAN THAT HAD MOST RECENTLY BEEN SQUEEZED OUT DURING THE EFFUSIVE ERUPTIONS

originates from the breaking of the magma itself, then catastrophic fracturing in pure obsidian is particularly challenging to predict. However, when the magma is not obsidian and contains just a small number of crystals, or bubbles (such as at andesitic volcanoes near subduction zones) the prediction of catastrophic events drastically improves.

Although our predictive tools are improving, they are far from operationally viable. Observation of magma fracturing, such as were made at the vent of Cordón Caulle volcano in 2014 and 2015, provide first-hand constraints on these processes.

Environmental impact

Cordón Caulle volcano erupted on 4 June 2011, developing a c.9-12 km high volcanic ash column in the first four days. The ash circled the southern hemisphere. The plume was less high in the following week, rising to between four and nine kilometresand decaying to below six kilometres from 14 June. The changes in height were caused by the eruption's variable pulsations. It is easy to see how challenging such eruptions can be for civil protection authorities, emergency managers and governments.

As a direct result, about 4000 people were evacuated. Prevailing winds carried the ash plume to neighbouring Argentina, causing widespread disruption. Subsequent phases of explosive activity continued into 2012, frequently affecting aviation locally and across several continents. In South America, the Volcanic Ash Advisory Centre (VAAC), hosted by the National Weather Service of Argentina, is responsible for issuing warnings based on volcanic ash dispersal models. In turn, national civil aviation administrators advise airlines on the atmospheric conditions related to the ash; but ultimately, the decision to fly or not is taken by individual airlines and pilots.

The ash particles are all formed in the fracturing and pulverisation process described above. In fact, volcanic ash particles consist of small particles of volcanic glass with variable amounts of crystal phases or vesicles preserved within them. The hazard posed by these fractured volcanic ash particles on the aviation industry is complex but ultimately comes down to the time- and temperature-dependent viscous sintering process, in which the tiny particles melt and stick to surfaces.

In this case, the surfaces to which they stick are the operational surfaces inside hot commercial jet engines. It has recently become clear that volcanic ash is particularly hazardous to commercial airline industry because the glass transition temperature at which the ash becomes sticky is a lot lower than the melting points of other dust materials which are ingested by jet engines, such as desert sands.

Wonder and awe

These exciting new scientific ideas about obsidian's formation require thorough testing and discussion. But this does not detract from the wonder and awe that obsidian still engenders. Volcanologists today remain fascinated by the secrets and remaining mysteries of this enigmatic material. The wealth of history recorded by these enigmatic stones drive us to explore what may seem at first to be arcane theoretical ideas far from everyday concerns. But what we learn leads us closer, we believe, to finding the causes and dynamics of explosive activity, and thus enable us to mitigate the hazards for those who must live under the volcano. ◆

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11 January 2015. The dynamic landscape into which the eruption intruded is built of steep gullied sands that make hiking very difficult

January 2015. The view from within the vent. We noticed that the black obsidian lava contained fracture surfaces coated with oxidized layers, which under the electron microscope appear to be sintered layers of volcanic ash from the large explosions

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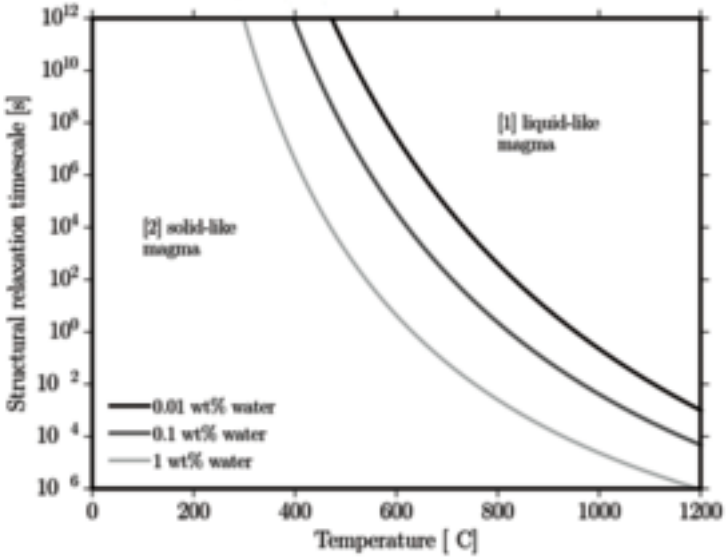
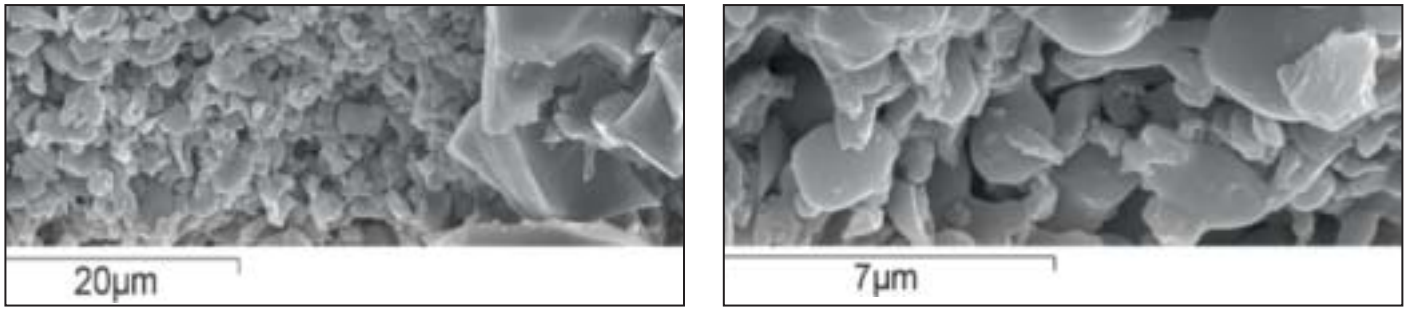


If magma is hot or locally flowing slowly, it occupies region [1] and exhibits a liquid-like response. If cooler or moving rapidly, it occupies region [2] and exhibits a solid-like response. Curves mark the approximate transition for magmas with different dissolved volatile water contents. During ascent, magmas probably cross this transition many times, breaking, flowing and healing in repetitive cycles. Drawn using models developed by Donald B Dingwell and his team at Ludwig-Maximilians-Universität, Germany.



Two SEM images of sintered volcanic ash particles adhering to fracture surfaces and forming the smooth veneers seen in field outcrops. Magma that is pulverised to a powder of volcanic ash sticks back together again in hot cracks even as it is being violently erupted.

January 2014. The view down on the obsidian source. The obsidian lava was squeezed out from here away from the photographer (Hugh Tuffen)

January 2014. The red veneer is a coating of fracture surfaces with sintered volcanic ash. This tells us that these fracture surfaces were channels for the overpressured gases and ash to escape through the lava as it was being squeezed out

GROUND TRUTH

Photos Nautilus Ltd: course N009

Gary Nichols* makes the case for field-based training in the oil and gas industry, and why it is integral to Chartered status


Photos Nautilus Ltd: course N108


Photos Nautilus Ltd: course N108


Photo Nautilus Ltd: course N298

Above top: *Fluvial channel sandstone bodies with a sheet-like geometry*
Above middle: *Lens-shaped sandstone bodies formed by river channels. Both outcrops are from the Miocene of the Ebro basin and illustrate sandstone geometries that would behave quite differently as reservoirs*
Above lower: *Stratal geometries from the Cenozoic of Spitsbergen (a) Mountainside clinoform exposure at Storvola*

Left: *Examining a deep-water succession on a field course in County Clare, Ireland*

In 2014, this magazine's 'Soapbox' column (and, subsequently, the Letters pages) hosted a kind of spontaneous flashmob discussion of the role of fieldwork in the teaching of geology. The attraction of working outdoors may not be for everyone; but the question of assessing the relative value of 'seeing rocks in the field' against seeing them via the medium of a computer screen, remains.

There is no doubt that remote-sensing, virtual reality outcrops and rapid geochemical analysis have all significantly improved our ability to understand the Earth. This increasing use of technology in our science has started to shift the emphasis away from observational field studies, and thus the case for continuing to send geoscientists into the field has to be made with specific, tangible (and, yes, economic) arguments. This article will focus on petroleum geoscience; but similar points could be made about other strands of our science.

Employment

Every year, hundreds of students with BSc, MSci, MSc and PhD degrees from UK universities seek employment in the oil and gas industry. Their preparation for a job will probably include a first degree in which a number of weeks spent in the field were a compulsory element of the programme, providing them with awareness of a wide range of geological phenomena. A specialised Masters degree will also have included some field courses, but few will have undertaken a field-based project. To help encourage more MSc students to include fieldwork, CASP (a research organisation based in Cambridge, specialising in field-based studies for the energy industry) offers an MSc student scholarship that includes a fieldwork bursary.

The proportion of field-based PhDs has decreased over the years - partly due to funding pressures, but mainly due to trends in academic research, which have shifted in emphasis towards more instrument-based topics. However, the recent creation of the NERC Centre for Doctoral Training in Petroleum Geosciences (Heriot Watt University – see below) will help to ensure that students who do their PhDs under this scheme will have the benefit of a series of field courses as part of their training.

Industry training

What is important, when these students enter the industry, is that field training remains integral to their Continuing Professional Development. The oil and gas industry has a good record of providing on-going training to their professional staff (see Letters, p. 21). This has been made evident over the past year, during a period of falling oil prices. Most companies have maintained a programme for their staff (albeit scaled back). Very few have stopped training geoscientists altogether, while some have increased their commitments, despite having laid staff off.

To quote a particularly enlightened company: 'We now have to operate with fewer people, so they need to be better trained'. Budget constraints have resulted in travel restrictions, so attendance on field courses across the Atlantic has become rarer; but many hundreds of oil and gas company geoscientists are still attending field-based training courses this year. The message is clear: despite all the uncertainty, doom and gloom of an oil price half what it was a year ago, CPD training is still valued in the industry, and field courses still have a place.

This raises the question of why field-based training is seen to be important for professional geologists in the industry – important enough to be paid for, even as budgets are being cut. The answer lies in the technological advances that have been made in the last couple of decades: not in what these new technologies can do but in what they cannot. As a result of advances in data processing, 3D seismic now provides imagery of the subsurface in a degree of detail unimaginable just a decade or so ago. However, the resolution is limited to tens of metres vertically and horizontally, meaning that anything at the scale of metres cannot be characterised. The quality of down-hole data from conventional well-logs and borehole imagery has similarly improved and, along with core, provides detail at the sub-metre scale, but only in the vertical dimension. ▶

> "DESPITE ALL THE UNCERTAINTY, DOOM AND GLOOM, CPD TRAINING IS STILL VALUED IN THE INDUSTRY, AND FIELD COURSES STILL HAVE A PLACE"


Photos Nautilus Ltd: course N298


Photo Nautilus Ltd: course N011


Photo Ken McClay, Nautilus course N016

Above: *Town of Tete from the north shore of the Zambezi, by T Baines1859, oil he north shore of the Zambezi oil he north shore*

Above left: *Stratal geometries from the Cenozoic of Spitsbergen (b) details of slope facies*
Lower left: *Extensively exposed shoreface facies in the Book Cliffs, Utah*

Limitations

The limitations of seismic and borehole data become apparent when attempting to create a model, conceptual or numerical, of a body of rock that may be an oil or gas reservoir. The heterogeneities that will determine how a fluid will flow through it exist at a scale that cannot be resolved on seismic data, and horizontal complexities cannot be extrapolated between boreholes that may be kilometres apart. The only way to conceptualise reservoir characteristics is to use analogues from outcrops of comparable depositional setting.

The problem then is deciding which analogue to use. Taking an example of fluvial channel sandstones: is it better to use the sheet-like sandstone geometries as an analogue, or assume that the sandstone occurs in lenses (see pictures)? Both of the examples shown are outcrops of Miocene fluvial strata from the Ebro Basin (N. Spain). Seeing these two outcrops, along with many others, on a field course focusing on the characteristics of fluvial depositional systems does at least provide a reality-check on reservoir models.

Seeing the units filling a sedimentary basin in the field allows you to appreciate their geology at a wide range of scales. The sandstone units of a potential reservoir can be examined at a metre and sub-metre scale when standing in front of a rock face; samples can be viewed with a hand-lens, allowing characteristics at and below millimetre-scale to be observed. Looking away, lithological units that are laterally equivalent, or stratigraphically above and below can be seen, and in areas of good exposure the geometrical relationships over kilometres traced, perhaps across large swathes of country.

Where exposure is especially good, it is possible to make direct links between what can be seen on a seismic scale, and the scale of an outcrop. This is the case in Cenozoic strata on Spitsbergen where a spectacular mountainside exposure shows a clinoform structure (picture). Most importantly, it is possible to traverse the whole structure and see the clastic facies variations from marginal marine to slope deposits, with their small-scale soft sediment deformation.

Deepwater successions are exploration targets in many parts of the world, so it is important to see large-scale facies relationships in the field - in places like the Karoo (South Africa). Other examples include the complex fold and thrust geometries in the Spanish Pyrenees and French Alps, and their controls on stratigraphic relationships; or exposures of shallow marine facies and their sequence stratigraphic relationships traceable for tens of kilometres in the Book Cliffs of Utah.

Any geoscientist who sees geological features in the field like this will come away with a better understanding of the processes that produced them, and thus better equipped to interpret subsurface data.

No stopping

Evidence of continuing training is an important criterion in attaining and maintaining Chartered status (CGeol). For petroleum geoscientists a widely-held consensus within the industry holds that field-based training is a fundamental element of CPD, from learning core concepts in graduate programmes, to advanced, specialist courses for those with a decade or more's experience.

Trotting out H H Read's dictum that the 'best geologist is the one who has seen the most rocks' (see Letters, p. 21) is no longer enough; but it is easy to provide tangible examples of how experience of seeing geological features and relationships in the field can significantly enhance a geoscientist's ability to do his or her job in oil and gas. Seismic and borehole data can provide opportunities for sophisticated interpretations of the subsurface. Those interpretations, however, need to be reality-checked by comparison with rocks in the field and the scale limitations of these data recognised through seeing the complete picture - in outcrop. ◆

FURTHER READING

For more information on the NERC Centre for Doctoral Training in Oil and Gas go to **www.hw.ac.uk/schools/energy-geoscience-infrastructure-society/research/postgraduate/opportunities/centre-for-doctoral-training-in-oil-and-gas.htm**

* **Gary Nichols** is Managing Director, Nautilus Ltd (part of RPS Group). Nautilus is the largest single provider of field-based training for geoscientists in the oil and gas industry. The programme of geology, geophysics and professional skills development courses offered by Nautilus is accredited by the Geological Society and can form part of a development pathway to achieving Chartered status

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Lyell Meeting 2016

Paleoinformatics: Synthesising data from the past to illuminate the future

9 March 2016

The Geological Society, Burlington House

Synthesising palaeontological occurrence data and taxonomy into useable databases and web-systems will be one of the major challenges for palaeontology over the next couple of decades. On the one hand compiling palaeontological data and integrating it with other databases has immense research potential in fields from palaeoceanography and climate change through to palaeobiology. On the other hand there is an ever increasing expectation that information, on virtually everything, should be available electronically via the web. In both areas palaeontology is nowhere near as advanced as we might hope and there are major challenges for the future – not least since there are particular information technology problems in handling and standardising taxonomic and stratigraphic data.

The purpose of this meeting is to bring together researchers who are playing lead roles in significant current initiatives and/or who have carried out particularly interesting individual work, with the objective of sharing experience and showcasing good practice for the large numbers of other workers who are interested to develop or improve palaeoinformatics within their own work.

Convenors:

Ken Johnson (Natural History Museum)

Jeremy Young (University College London)

Further information:

For further information about the conference please contact:

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

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Falling metal production driven by falling demand, not availability

Hubbert not applicable

Sir, The article concerning the availability of mineral resources addresses an important global challenge (*Limits to growth revisited, Geoscientist 25.09, October 2015*). However, we take issue with the methods used by the authors and the validity of many of the underlying assumptions they make in concluding that resources of many metals and minerals will be physically depleted within a timescale of a few decades.

The authors take data and definitions of resources and reserves from the USGS and apply them in a wholly inappropriate manner. They fail to appreciate that reserves are dynamic economic entities that are neither fixed nor well known for any metal or mineral. Consequently reserves are not reliable indicators of future availability. Mineral supplies are determined by the market. As demand and prices have risen, so new reserves have been mined and supply has remained secure. At the same time users have improved resource efficiency and increased substitution and recycling.

The application of 'Hubbert's Peak' to metals production is contentious and does not necessarily "work excellently on any non-renewable mined geological reserve," as the authors claim. The authors do not consider the broader literature and reference their own work as proof of its validity. Historical records show that production of metals is closely linked to prices, with intermittent peaks and troughs driven by economic cycles. Thus declining production is generally driven by falling demand rather than by declining resources.

We in the economic geology community contend that we will reach environmental limits far sooner than physical limits. This article distracts from the research and innovation required to sustain mineral supplies from primary and secondary sources, while radically reducing the environmental footprint of our resource consumption.

DR JONATHAN NADEN AND 12 OTHERS

Hydrogeology threatened

Sir, Your editorial about 'Water Wars' and the feature by John Simmons on Water and Energy *(Geoscientist 25.10, November 2015)* draw attention to the need for comprehensive understanding of geology. Knowledge of groundwater conditions in many aspects of our lives in a coherent developing society tends to be overlooked, or taken for granted. Understanding aquifer hydrogeology is essential for groundwater supply, not only in temperate countries like the UK, but also particularly in the vast regional sedimentary basins and 'hard rock' terrains in arid regions. With population increases and greater demands on supply, the need for definitive hydrogeological understanding also increases and will continue as aquifers become more stressed with climate change.

While groundwater supply may be the most obvious hydrogeological activity, in many cases environmental issues dominate, requiring in-depth appreciation of complex hydrochemical reactions coupled with an understanding and ability to represent hydraulic controls. Waste disposal is heavily regulated with hydrogeological criteria, which will become paramount in eventual decisions about UK nuclear waste burial. Understanding construction and mining impacts on groundwater systems frequently prove essential for success and gas fracking is now widely seen as a hydrogeological issue.

Clearly, while geology is the framework for groundwater, understanding functionality is a multi-disciplinary task involving physics, mathematics, chemistry etc.. This normally requires an advanced education above that of the standard BSc.

Over the years UK universities have supported various Hydrogeology MSc Courses essentially integrated with research programmes. Most have now closed and the closure of the most successful course, at the University of Birmingham, is now mooted. In a country where skill shortages are a daily lament, one can only suggest that there seems to be a disconnect between those funding and operating higher education and the requirements of the wider community.

JOHN LLOYD

The golden age of fieldwork

Sir, Desmond Oswald's obituary *(Geoscientist 25.9 October 2015),* highlighted the role of field party chiefs in the golden age of geological fieldwork. It was one of his most important functions between 1950 and 2000, when all the major domestic and international oil companies sent geological parties into the field.

This was a period of intense study of the structure and stratigraphy of the Western Canadian and Arctic sedimentary basins. Some of the most significant contributions to the geology of mountain belts originated as field party chiefs' reports.

The activities of oil company field parties, reported by field-party chiefs in company reports and eventually published in national and international geological journals, contributed as much as the Geological Survey of Canada to the understanding of the geology of mountain belts in Canada and worldwide. Desmond Oswald was a field party chief for Chevron, and was outstanding. Bob Stoneley performed a similar function for BP. There were dozens of others throughout the petroleum industry. For almost 50 years, geological fieldwork carried out by oil company field parties was an important but generally unrecognised element in petroleum exploration in Western and Arctic Canada.

PETER B JONES

Poor argument

Sir, Edward Jones, in his article, 'Towards a Moral Geology' *(Geoscientist 25.10, November 2015)* opines: "My only solution to this [problem of human-produced CO_2 leading to climate change] is that we should not take any more oil out of the ground."

His solution is not morally well thought-out. Assume that the World's Grand Pooh-Bah existed and followed Jones' solution forthwith. The catastrophic impact on the world's population from immediately stopping the use of all petroleum-based products would far exceed the more gradual impacts of taking no steps to reduce greenhouse gases and allowing the most direly predicted impacts of global warming to occur. Moral solutions to global warming must take both present and future impacts on society into account.

DAVID M ABBOTT JR

15-17 November 2016

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GLOBAL

FUTURE FRONTIERS

With a highly volatile oil price environment, investors shy away from high risk / high cost basins Arguably, that is the time for explorers to discuss the next wave of opportunity.

Talks are invited on:
- Frontier basins and exploration
- Unconventionals outside of North America – what happens next?
- New petroleum systems
- Enabling technologies in frontier basins

EMERGING BASINS

Significant discoveries in West Africa, Egypt and the equatorial margins of South America in 2015 suggest that there are new plays to be found. Where are the emerging basins?

Talks are invited on:
- Recent discoveries and their implications
- High impact wells
- Regional play concepts
- Onshore basins
- Low-cost exploration
- Development strategy
- Enabling technologies in emerging basins

MATURE BASINS

Under-estimated resource potential, bypassed pay, undrilled plays & near field exploration. Mature basins present opportunities and challenges at all scales of E&P.

Talks are invited on:
- New hydrocarbons in mature basins
- Near-field exploration
- Exploration strategies in mature basins
- How to secure future production
- Enabling technologies in mature basins

NORTH SEA

OPPORTUNITIES

With a number of larger E&P companies rationalising their portfolios in the North Sea, opportunities remain for investors, particularly the more agile players.

Talks are invited on:
- New play types and play extensions
- New insights into existing plays
- Recent exploration and appraisal
- Near field exploration
- Enabling technologies to maximise these opportunities

CHALLENGES

The number of exploration wells dropped from 31 in 2010 to 16 in 2015. There is an increased risk of decommissioned infrastructure with low oil prices as high costs continue to bite.

Talks are invited on:
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- How we mitigate against them
- Updates on key projects
- New volumes in existing fields
- Enabling technologies to overcome these challenges

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Biomass in the Energy Industry

Biomass is an increasingly important component of the energy landscape and biomass coupled with bioenergy is seen by many as an essential step in the transition to a sustainable energy economy. This book is a broad introduction to benefits and potential limitations of biomass and explains in broad terms what crops and potential crops are suitable for use in various scenarios. The authors explain where biomass fits into the world energy model and how a greater uptake of biomass can help mitigate the increasing volumes of CO_2 in the atmosphere. This book has its origins in the BP Energy Sustainability Challenge and is one of several introductory books on topical subjects examining energy industry practices generated by the sustainability challenge.

The text is well laid out and leads the reader through concepts associated with biomass and its potential with clear diagrams, maps and charts before moving onto the economics, politics and environmental concerns that influence where biomass can be grown. The tone is direct; it reads like a student textbook rather than an academic tome, and is easily accessible to various audiences. As with the other books in the BP energy and sustainability series it has extensive references, with the key references highlighted after each chapter so the reader can follow up on specific lines of enquiry.

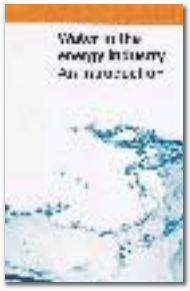
The book itself is well made and printed on quality FSC-certified Cocoon Silk, but more relevant is the fact that this book can be downloaded free as a PDF from BPs own website along with its companion texts for supply chain and water use.

This volume is aimed at a very broad audience. Being an introductory text, I can see it being of great use to policy makers and teachers as well as engineers and scientists wishing for a greater understanding of biomass and its contribution to mitigating climate change. While a good introduction to a very relevant subject, the data pertaining to regional growth of biomass and volumes shipped, as well as politics and economics will become dated very quickly, such is the speed of development in this area. Overall I was impressed with the breadth and depth of coverage of biomass in such a short introductory volume, this is an excellent overview of a very relevant topic and being available as a free download it is definitely worth a look.

Reviewed by ***John Midgley***

BIOMASS IN THE ENERGY INDUSTRY: AN INTRODUCTION
by Davis, S C, Hay, W & Pierce, J, 2014. Published by BP and ON Communications, 117pp (pbk) ISBN: none
List price: FREE - available to download at W: www.bp.com/energysustainabilitychallenge

Water in the Energy Industry



This book (the basis of John Simmons' recent feature article in *Geoscientist 25.10*) is the summary of the water component of the BP Energy Sustainability Challenge and is framed as an introduction to water used in a comprehensive range of energy industry applications and is not limited to activities in which BP themselves engage. It is one of several introductory books on topical subjects examining industry practice generated by the Sustainability Challenge and the processes and results can be applied to a range of operators and allied industries.

Several important messages are held out by this book. The main one is that at least one major player in the energy industry recognises water issues, specifically source, volumes used, waste disposal and sanctity of resources are all very important to their continuing in business. The authors recognise it is a shared resource and that it must be used sustainably with reference to the commodity itself and also with reference to society.

The book is well laid out, with clear chapter and subject headings, and makes good use of diagrams, schematics and charts to illustrate the discussion. There are clear side-boxes to explain the chemical processes and points of information, and the explanation of units and conversation factors are at the front of the book to orient the reader, not hidden away at the back to be searched for.

The use of water within various industrial scenarios, including shale gas, nuclear, carbon capture and storage (CCS) and enhanced oil recovery (EOR) are examined, with clear referencing for data sources and well annotated schematics showing the processes that use water. Each chapter has a section that discusses risks, opportunities and innovations, as well as a chapter summary and an extensive list of references.

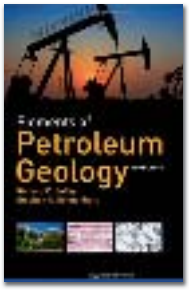
The book itself is well made and printed on quality FSC-certified Cocoon Silk, but more relevant is the fact that, as with the previous volume reviewed (above) the book can be downloaded free.

This book is intended for a very broad audience of engineers, environmentalists, sustainability managers and students as well as an interested general public. Although described as an introduction, it will possibly be the only text on the subject that many readers will require. If the reader does need more detail, or to know where to find more information, the well laid-out lists of references will help.

Reviewed by ***John Midgley***

WATER IN THE ENERGY INDUSTRY: AN INTRODUCTION
by Williams E D and Simmons J E, BP, 2013. Published by BP and ON Communications, 107pp (pbk) ISBN: none.
List price: FREE - available to download at W: www.bp.com/energysustainabilitychallenge

Elements of Petroleum Geology



Elements of Petroleum Geology is an overview of nearly all aspects of petroleum geology and how they are connected. The last edition (2nd) was published back in 1998 and has been overdue a revision to reflect more recent technology and industry practice. In the latest edition, the style of writing, order in which aspects of petroleum geology are addressed and clear layout of equations have been retained. This makes the book a very good *aide mémoire* for professionals as

well as a comprehensive textbook for students. Throughout the book the voice is authoritative and the text concise. Complex concepts are explained in a clear manner, especially those related to sedimentary environments reflecting the authors' areas of expertise.

In the 3rd edition, the chapters and layout have not changed from previous editions. The text appears to be largely the same, with additional sections on horizontal drilling and hydraulic fracturing. I did not find any additional material for carbon storage or enhanced oil recovery, two topics that appear to be falling within the remit of petroleum geologists. There is new material on adsorption and absorption in source rocks that use clear colour diagrams, highlighting the contrast with the majority of illustrations carried over from earlier editions which remain predominantly black and white.

The version of the book I received for review was the electronic edition. While not having the familiarity of a print edition for a quick flick through, it does have the advantage that the many of references can be accessed via the internet by a quick click on the hotlink. The downside is 'link rot' - many are now defunct! Given that the references are hyperlinked, I expected the index to have the same ability and link to inline text; alas it does not - another opportunity missed to exploit the potential advantages of eBooks.

Elements of Petroleum Geology has been the book I recommend most often to mudloggers and wellsite geologists who want to fill their knowledge gaps or gain a wider perspective on practical petroleum geology. I will continue to recommend it to all prospective students who wish to pursue a geoscience or engineering career in the oil industry, especially if they expect to be closer to the rig-end of the business. This is an expensive book, especially for students. If one is considering a purchase, think carefully about which format, print or electronic, best fits your needs.

Reviewed by ***John Midgley***

ELEMENTS OF PETROLEUM GEOLOGY 3RD ED.
by Selley, R C and Sonnenberg, S A, 2015. Published by Elsevier, 527pp (electronic book version as PDF) ISBN: 978-0-12-386031-6 (print) / 978-0-12-386032-3 (eBooks)
List price: £69.99 W: http://store.elsevier.com /Elements-of-Petroleum-Geology/Richard-Selley/isbn-9780123860316/

Global Heritage Stone

The designation of Global Heritage Stone Resource (GHSR) is intended to assist in the recognition of the materials from which so much of the 'built heritage' is constructed and to ensure their supplies for future projects (including restorations). The utility of the designation will depend, of course, on its relationship to local laws and regulations and, while such matters are discussed at length in some of the papers in this work, this reviewer was not convinced that a clear and unambiguous case (other than one of general worthiness) has been made.

According to the introductory remarks of the editors, most of the papers included reflect presentations made at the EUGS General Assembly in 2013, supported by contributions from other authors 'enthusiastic about the concept' of GHSRs (and the related designation Global Heritage Stone Province, GHSP, a geographical area containing two or more GHSRs). The responsibility for awarding these accolades falls to the Heritage Stone Task Group (HSTG), a joint project between IUGS and IAEG.

The guidelines and checklists designed by the HSTG are well-documented and contextualised in this work, but several of the papers repeat these, an issue which I found somewhat irksome and one of the few negative points of the book. The papers vary greatly in length and technical detail and cover proposals for specific GHSRs, reviews of history and utilisation of specific rock types (shamefully I had to Google 'Scottish rubble'….), the description of potential GHSPs (e.g. southern Slovenia and the Minas Gerais region of Brazil) and details of the variety of rock types used in particular settings (St Petersburg, the Via Roma of Turin).

The editors have done well in compiling such a broad range of papers and this prevents the book from becoming a collection of sterile technical papers of specialist interest only. It is a compilation full of interest to the 'general' reader and I genuinely enjoyed reading it. There are detailed histories and descriptions of some old friends (larvikite, Carrara Marble) and many fascinating technical and historical details of stones and provinces that are probably poorly known to many readers of *Geoscientist*.

This could be an important volume to have to hand for those involved in geoheritage projects and many of its papers would be of interest to the more general reader who simply 'loves' rocks (and who doesn't?).

Reviewed by ***Trevor F Emmett***

GLOBAL HERITAGE STONE: TOWARDS INTERNATIONAL RECOGNITION OF BUILDING AND ORNAMENTAL STONES
by D Pereira, B R Marker, S Kramar, B J Cooper and B.E. Schouenborg (editors). Geological Society Special Publication No. 407. Published by The Geological Society London 275 pp (hbk) ISBN: 9781862396852
List Price: £90.00. W: www.geolsoc.org.uk/bookshop.

BOOKS Available for review

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

- **NEW! Rock Deformation from Field, Experiments and Theory** by D R Faulkner et al (eds) 2015 Geological Society Special Publication #409 277pp hbk
- **NEW! Tertiary Deep-Marine Reservoirs of the North Sea Region** by T McKie et al (eds) 2015 Geological Society Special Publication #403 407pp hbk
- **NEW! Magnetic Susceptibility Application** by A C Da Silva et al (eds) 2015 Geological Society IUGS Special Publication #414 283pp hbk
- **NEW! Industrial Structural Geology** by F L Richards et al. (eds) Geological Society Special Publication #421 267pp hbk
- **NEW! Chemical, Physical and Temporal Evolution of Magmatic Systems** by L Caricchi et al. (eds) Geological Society IAVCEI Special Publication #422 223pp hbk
- **NEW! Moons - A very short introduction** by David Rothery 2015. Oxford University Press 153pp, flexicover.
- **Petroleum Geology of Myanmar** by Racey and Ridd. Geological Society Memoir #45. 2015 sbk 123pp
- **NEW! Volcanic Geology of Sao Miguel Island (Azores Archipelago)** by Gaspar et al (Eds) Geological Society Memoir #44, 2015 hbk 309pp
- **Current Perspectives on Zinc Deposits,** by Archibald and Piercey (Eds). Irish Ass. for Econ. Geol. 2015 251pp, hbk.
- **The High Mountain Cryosphere - environmental changes and human risks.** Edited by Christian Huggel et al., Cambridge University Press 2015363pp, hbk.

PEOPLE *NEWS*

CAROUSEL

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

◆ Phil Gibbard

Has been invited to take up the prestigious post of Secretary-General of the International Commission on Stratigraphy (ICS). The post, which was announced on Saturday 7 November, is initially for four years for the period 2016-2020.
The ICS is the largest and oldest constituent scientific body in the International Union of Geological Sciences (IUGS

◆ Maria Iredale

Has been appointed Executive Director of the PESGB from January 2016, in succession to Guy Elliott. Maria says: "I have an arts charity background and my geology/petroleum exploration industry knowledge is limited (though I am studying furiously!). I am going to be working with the PESGB team and Council to make sure our organisation can offer you all you need in these challenging times."

◆ Simon Little

Has been appointed Senior Manager in global environment and health consultancy Ramboll Environ's Site Solutions team. Based in Edinburgh, Simon has 25 years' experience in geological and environmental consultancy and specialises in land quality and water environment risk assessments and remediation. He holds an MSc in Hydrogeology from the University of East Anglia.

Where is it?

Steve Cribb is interested in crowdsourcing information about a watercolour by one 'P Willett', about which he knows absolutely nothing.

Photo: Alison Hunter 2011

Steve writes: "I bought it in Melrose some years ago just because I liked the subject and interpretation. It is bold and certainly 'geologically' interpreted. However I do not have a clue as to where it is! The picture was framed at a shop on the Wirral and I suppose it has a North Walian feel. Could those be volcanics in the foreground?"

➤ If you have any information or suggestions, please email **Steve** at **stephen.cribb9@gmail.com**

Careers Day 2015

The Society convened two Careers Days last year, at BGS, Keyworth (November 18) and Our Dynamic Earth in Edinburgh (25 November), respectively attracting 300 and 211 attendees, and 23 and 13 Exhibitors. Presentations were given on Engineering Geology, Hydrogeology, Contaminated Land, Mineral Exploration and Mining, Oil and Gas, Chartership, Geohazard Risk Assessment, Geophysics, Urban Geology, Renewables, and post-doctoral research, as well as the ever-popular CV and careers workshops.
Dawn Riddle

IN MEMORIAM WWW.GEOLSOC.ORG.UK/OBITUARIES

THE SOCIETY NOTES WITH SADNESS THE PASSING OF:

Barker, R W N *
Bishopp, David *
Colley, H *
Flood, Raymond Edward *
French, Bill
Gorsline, Donn *
Grinly, David *
Haddow, Douglas *
Kenyon-Smith, Alec (Alec Smith)
McNicholas, J B *
Terris, Alexander P *

In the interests of recording its Fellows' work for posterity, the Society publishes obituaries online, and in *Geoscientist*. The most recent additions to the list are shown in bold. Fellows for whom no obituarist has yet been commissioned are marked with an asterisk (*). The symbol § indicates that biographical material has been lodged with the Society.

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

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

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

DISTANT THUNDER — *Goody bags*

Geologist and science writer Nina Morgan* wonders what to do with freebies

If you've ever attended a conference, you'll know what I'm talking about. Those goody-bags filled with leaflets, brochures and various small 'gifts', some useful, some not, emblazoned with sponsors' names. Most of us find it easy enough to dispose of any unwanted items. But spare a thought for those who must not only graciously accept, but also find a place to display, these sometimes unsolicited gifts.

In his garden at Highgrove, near Tetbury in Gloucestershire, HRH Prince Charles has come up with one answer. The large collection of busts he has received over the years representing people he admires, along with a significant number of busts of himself at various stages of his life, are cleverly and artistically displayed around his lovely 15-acre garden. Presumably when he receives gifts while travelling abroad, his staff is responsible for ensuring their safe transport back to the UK.

But this option is not open to everyone. Spare a thought, then, for Roderick Murchison (1792-1871) who, while on a geological expedition in 1843, was presented with a gift from the Emperor of Russia in recognition of his geological skills in interpreting the geology of his country. The gift, described by Murchison's biographer, geologist and author Archibald Geikie (1835-1924) consisted of:

"... a great vase of Siberian aventurine [a variety of quartz], four feet high and six feet in circumference.."

The vase, which rested on a massive porphyry pedestal bearing the inscription:

Gratia Imperatoris Totium Rossiæ
Roderico Murchison
Geologiæ Russiæ Exploratori
MDCCCXLIII

which in turn rested on a steel plate an inscription in Russian which translates as:

To the Geologist Murchison
In Testimony of the Particular Esteem
The Administration of Miners of Russia

It was truly a rare and unusual gift. As Geikie notes:

"Owing to the difficulty of obtaining so large a block, and of polishing such a hard material, only one other similar vase has been made, viz., that presented to Humboldt, and now in the Royal Museum, Berlin."

But far from feeling inconvenienced by this gift, Murchison appears to have been both pleased and sanguine. He noted in his journal:

"How shall I ever render my work worthy of such a largess!! So now to bed to sleep over my honours."

Acknowledgement
Sources for this vignette include *The Heyday of Natural History* by Lynn Barber, first published in 1980 by Jonathan Cape, and Life of Sir Roderick Impey Murchison, vol 2, published by John Murray, London, 1875.

***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

Glossop Evening 2015

The Glossop Lecture 2012 was given by Dr Ruth Allington

Ian Duncan (Chair, Engineering Group) and David Manning (President, Geological Society) introduced this year's Glossop Evening at Burlington House on November 4. The Glossop Lecture 'Control the Drainage – the gospel according to sinkholes' was delivered by Tony Waltham (Nottingham Trent University), who received the Glossop Award from Silas Slack, Rudolph Glossop's grandson. The Glossop Award was received (in absentia) by Yung Loo (Arup). *Ted Nield*

OBITUARY LEIGH WESTON 1981–2015

Associate Geologist with SLR Consulting whose tragically early death robbed his workmates of a kind, professional and passionate colleague

Weston, who was an Associate Geologist with SLR Consulting, based at the company's offices in Shrewsbury, passed away suddenly on 29 August 2015 at the age of 33. Leigh has worked for SLR for almost a decade since leaving university and had steadily been expanding his experience and responsibilities within the company.

Leigh was born in Shrewsbury in October 1981 and was an early and enthusiastic amateur geologist, visiting local sites such as the mine workings at Snailbeach in Shropshire and exposures on Wenlock Edge.

Staffordshire

After finishing his A-levels, Leigh spent his gap year tracking big cats at the Pidwa Reserve in South Africa, and then went to University in Staffordshire to read Geology. During this time he was awarded a student prize from the Institute of Materials and Mining. More recently, he was the recipient of the North Staffordshire Group Geologists Association's John Meyer medal, in July 2009.

Leigh joined SLR as a graduate geologist, getting involved at first in the sometimes unglamorous world of supervising drill rigs and their often colourful drilling crews.

> "LEIGH JOINED SLR AS A GRADUATE GEOLOGIST, GETTING INVOLVED AT FIRST IN THE SOMETIMES UNGLAMOROUS WORLD OF SUPERVISING DRILL RIGS AND THEIR OFTEN COLOURFUL DRILLING CREWS"

One of Leigh's early projects was peat-probing in Scotland, where fellow geologist Alan Edwards recalls meeting Leigh and that "it was a foul day and the job was long & arduous (lots of peat probe locations – many in the depths of a coniferous forest) – yet he had a wide smile on his face, very friendly and utterly professional".

In addition to fieldwork, Leigh became a skilled geological computer modeller being tutored by his former colleagues Paul Joel and Rob Davies. They both left SLR to pursue their geological careers elsewhere, leaving Leigh in charge of SLR's quarry design work using the LSS software.

Haematite

In the last few years, Leigh had been working on a wide range of projects ranging from mapping haematite deposits in Brazil, drilling kaolinite deposits in Cornwall and carrying out PERC assessments of deposits of aggregate and brick clay for a wide range of clients.

Leigh has been described by colleagues at SLR as "one of the kindest, cheeriest and most thoughtful people I have ever come across … always polite, extremely professional and, of course, passionate about geology". Colleagues who accompanied him on fieldwork recall his prodigious eating ability after a day in the field, with Leigh on the look-out for 'all you can eat' curry houses, or places selling triple-decker beefburgers. Yet despite this eating ability, Leigh kept himself very fit through a workout regime which rendered his sudden death all the more shocking to his family, friends and colleagues.

Leigh is survived by his parents Wendy and Ken, and by his brother and sister, Daniel and Lucy.

By **John Leeson**

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

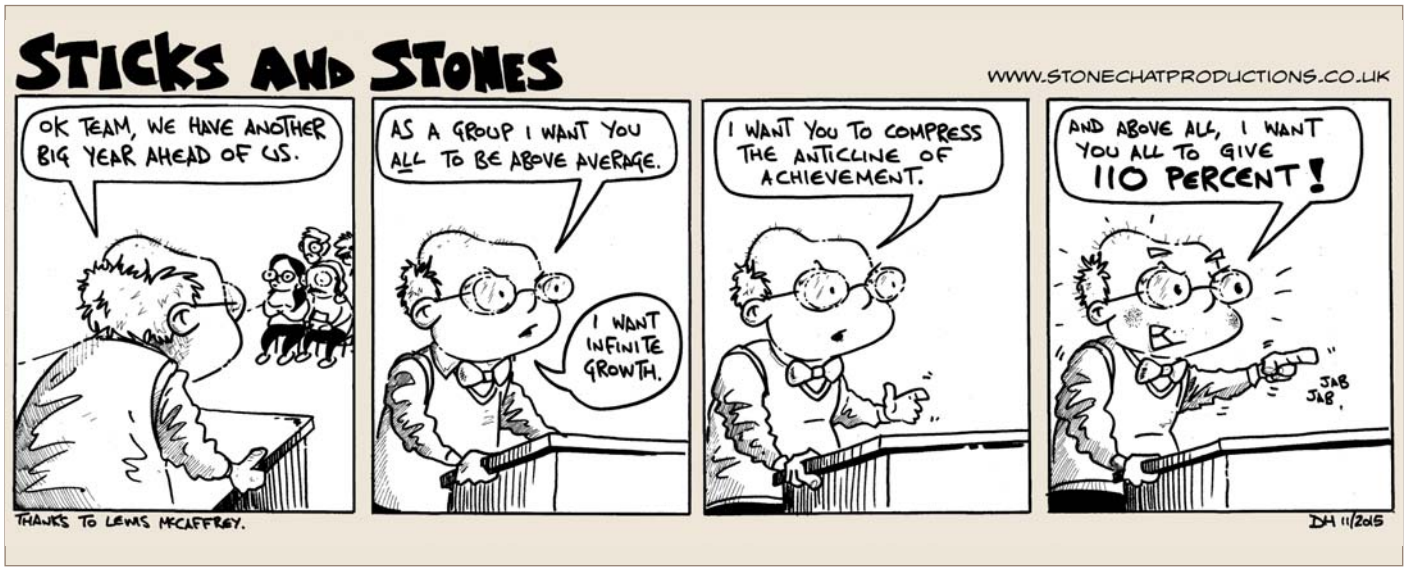
CAN'T FIND YOUR MEETING? VISIT WWW.GEOLSOC.ORG.UK/LISTINGS FULL, ACCURATE, UP-TO-DATE

ENDORSED TRAINING/CPD

COURSE	DATE	VENUE AND DETAILS
Introduction to Micromine	16-17 February	**Venue:** Micromine, Challoner House, 19 Clerkenwell Close, Clerkenwell, London, EC1R 0RR. Fees apply – see website for details Contact **E:** mmuk@micromine.com
Resource Estimation in Micromine	18-19 February	**Venue:** Micromine, Challoner House, 19 Clerkenwell Close, Clerkenwell, London, EC1R 0RR. Fees apply – see website for details Contact **E:** mmuk@micromine.com
Lapworth's Logs	n/a	'Lapworth's Logs' is a series of e-courses involving practical exercises of increasing complexity. Contact **E:** info@lapworthslogs.com. Lapworth's Logs is produced by Michael de Freitas and Andrew Thompson.

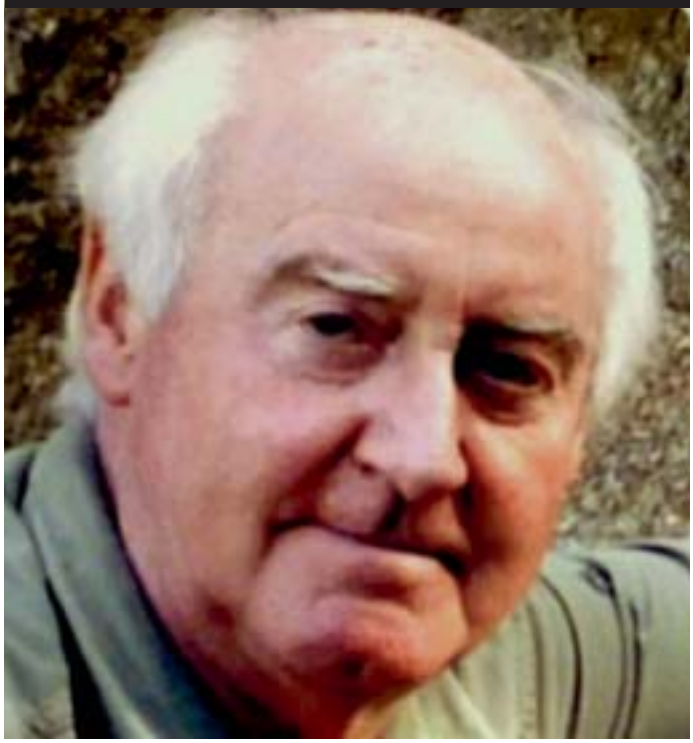
DIARY OF MEETINGS FEBRUARY 2016

MEETING	DATE	VENUE AND DETAILS
CIRIA Seminar North West Regional	TBA	**Venue:** TBA at time of writing. **Time:** 1830. Contact Nik Reynolds E: geologicalsociety.northwest@gmail.com
Construction dewatering in urban areas Engineering Group, BGA, GSL Year of Water	16 February	**Venue:** Burlington House. Time: 1730 for 1800. **Speakers:** Martin Preene - Preene Groundwater Consulting Ltd; Toby Roberts - WJ Groundwater, and Emilio Linde-Arias - OTB Engineering Ltd. Contact **E:** ursula.lawrence@capita.co.uk
Lavas that Burrow Southern Wales regional	17 February	**Venue:** LT1.40, School of Earth and Ocean Sciences, Cardiff University. **Speaker:** Dr Ian Skilling (University of South Wales). **Time:** 'Evening Meeting'. Contact: **E:** swales.rg@geolsoc.org.uk
The Formby Oilfields North West Regional, Liverpool GS	25 February	**Venue:** Manchester University. **Time:** 1830. **Speaker:** Dr Richard Worden. **Contact:** Nik Reynolds **E:** geologicalsociety.northwest@gmail.com



OBITUARY MIKE GOLDEN 1947-2015

Exploration geologist, consultant and polymath who specialised in Russian translation and retrieving vintage paper-era data



Mike Golden passed away peacefully on 31 August 2015. Mike was a talented geologist, an unparalleled friend whose social life was associated with PESGB and music.

Mike was a polymath: musician, scientist, linguist – fluent in Russian, French, Swahili and Ukrainian – environmentalist, gentleman farmer as well as a raconteur. His sense of humour was legendary.

He was born in 1947 in Greenock and attended the grammar school. His love of climbing and walking in the Scottish Highlands with their amazing geology made his decision to follow a career in geology a relatively easy one. He took his first degree at Glasgow University, followed by a PhD at Bedford College, London.

Bedford College

From his early days as a PhD Demonstrator at Bedford College, Mike was an enthusiastic mentor. Bedford's focus at that time was on the East African Rift and undergrads were regaled with stories of rock collecting in the Rift Valley (local tribesmen wielding sledgehammers while the post-docs drank pink gins!).

In 1971 Mike and Martha – another geologist – were married, and together they undertook fieldwork in Kenya, Finland, Sweden and Scotland before spending two years teaching at a university in Nigeria. On returning to UK, they bought Rowly Barn near Cranleigh with three acres, and set about turning it into a family home and smallholding. In the years that followed, they raised pigs, sheep, cows, chickens, dogs, cats and five children.

> MIKE WAS A MUSICIAN, SCIENTIST, LINGUIST - FLUENT IN RUSSIAN, FRENCH, SWAHILI AND UKRAINIAN

In the meantime, Mike worked as an exploration geologist with Esso and Amerada Hess. At Amerada Hess he established himself as an early authority on the exploration potential of West Africa and the West of Shetlands. His side-line was selling freshly butchered meat from his farm to staff, conveyed to the central London office by a conveniently passing data delivery service.

In 1992 Mike set up his own company, Golden and Associates, providing geological consultancy and specialist technical Russian translation services in oil and gas exploration. He also set up the electronic databases based on scanned vintage paper data. Collecting this was a real challenge as vintage stores were often literally decaying. Mike notably found key well-logs in an old shed under a sleeping stray dog.

Vivace Chorus

Music was another of Mike's loves. For over two decades he sang in the Vivace Chorus in Guildford. He had a wonderful bass voice, sight-reading skills, and was an incredibly friendly and supportive member of the choir: kind, gentle and generous, always ensuring that the singers got the pronunciation exactly right when singing in Russian.

Over the last two years, Mike's health deteriorated. However, in March 2015 he wrote: 'Although my knees are wobbly,…I have no plans to hang up my clogs and intend to die in harness'.

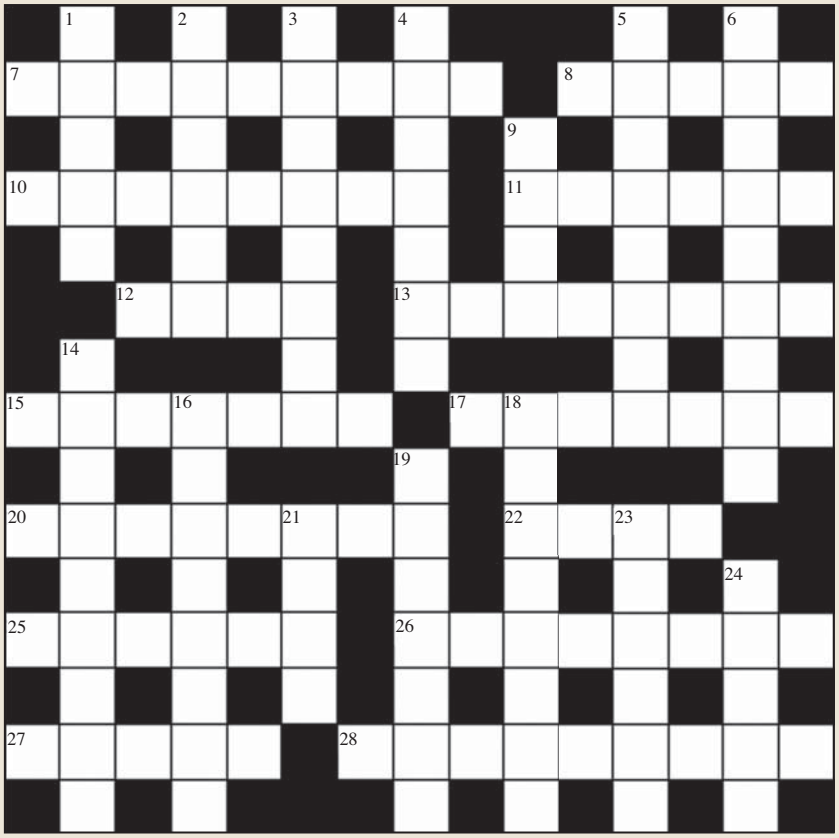
The end, when it came, came quickly. The day before he died, Mike was told by the doctors that they could do no more for him. "Well", he said, "I hope I can go out with good humour". And so he did. He spent the day with family members in what he jokingly called the 'departure lounge', remembering the many good times they had shared, telling stories, sharing jokes and laughing a great deal.

We will all miss him.

From **Mike's family, colleagues and friends who were helped, inspired and touched by Mike.** Shortened from a longer version available 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 Ted Nield at the Society.

CROSSWORD NO.199 SET BY PLATYPUS



ACROSS

7 Undersaturated aluminosilicate, found in intrusive and volcanic rocks and their associated pegmatites (9)

8 River, variously found in counties of Kent, Worcestershire, Warwickshire, Suffolk, Essex and Dorset. Not to mention New Zealand. (5)

10 State of gravitational equilibrium between Earth's crust and mantle (8)

11 Sedimentary bedding pattern created when a sediment is exposed to intermittent flows, leading to alternating sand and mud layers. (6)

12 This Leopold, father of Luna B, was a pioneer of environmental ethics (4)

13 Glacially displaced boulders far from their autochthon (8)

15 North Atlantic British overseas Territory famed for its reefs (and Triangle) (7)

17 River of ice (7)

20 Separate (8)

22 Tenth and last of the antediluvian patriarchs (4)

25 Orogenic phase in the late Mesozoic affecting much of Europe and points east (6)

26 Brown/yellow hydrated iron oxide mineral (8)

27 Once more (5)

28 Line of steep basaltic cliffs along the west side of the lower Hudson River in northeastern New Jersey and southern New York (9)

DOWN

1 A Shaking of the Earth (5)

2 With hammer, the essential tool of the palaeontologist (6)

3 Naturally occurring chemical compounds containing mostly basic nitrogen atoms (8)

4 Macromolecular biological catalysts (7)

5 Ocean separating Europe and Africa from the Americas (8)

6 Trilobitic knobs (9)

9 Triangular desert area of NE Ethiopia, site of continental rupture (4)

14 Study of causation (9)

16 Characterised by presence of micron-size calcium carbonate mud particles (8)

18 Vortex circulation aligned with the wind at the interface with bodies of water, often giving rise to eponymous streaks (8)

19 Related to the wind or the God thereof (7)

21 Paradisical garden of Genesis (4)

23 Metallurgical term for altering physical and sometimes chemical properties of metals by heating (6)

24 Primitive anaesthetic (5)

WIN A SPECIAL PUBLICATION!

The winner of the November Crossword puzzle prize draw was Matthew Taylor of Twickenham, UK.

All correct solutions will be placed in the draw, and the winner's name printed in the Issue April 2016. The Editor's decision is final and no correspondence will be entered into. **Closing date - February 29**.

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

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

Name .....

.....

Membership number .....

Address for correspondence .....

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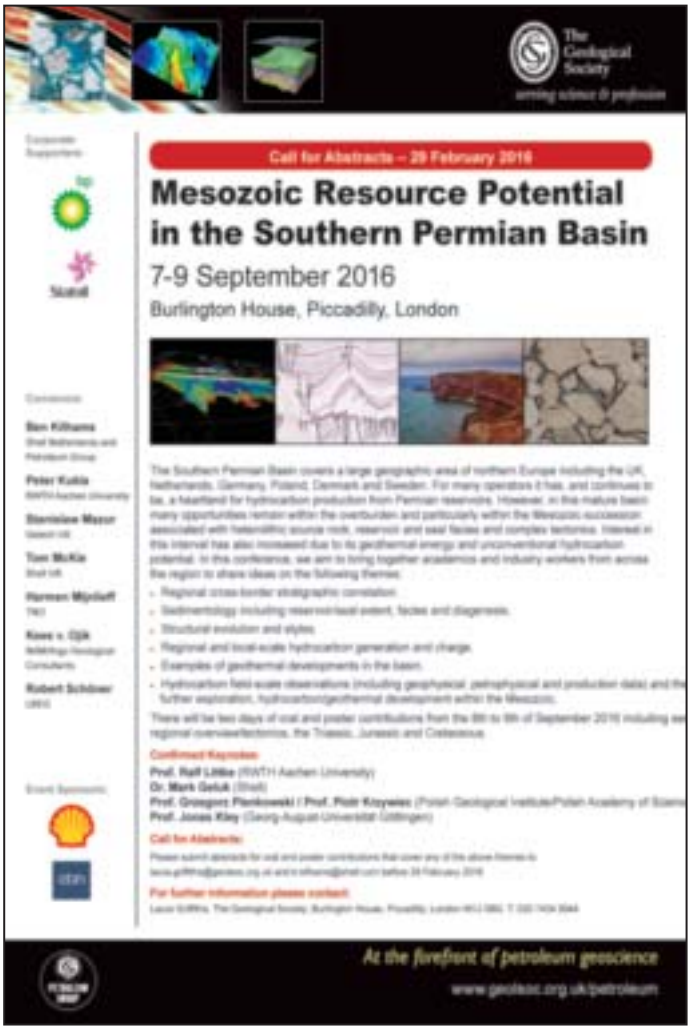
SOLUTIONS NOVEMBER

ACROSS:
7 Pegmatite **8** Abode **10** Regolith **11** larvae **12** Asti **13** Niagaran **15** Chicago **17** Britoil **20** Creosote **22** Dips **25** Spasms **26** Roentgen **27** Adits **28** Accessory

DOWN:
1 Meter **2** Emboss **3** Striding **4** Etching **5** Aberrant **6** Adiabatic **9** Alga **14** Theropoda **16** Crossite **18** Reddened **19** Bedrock **21** Oast **23** Potash **24** Peary



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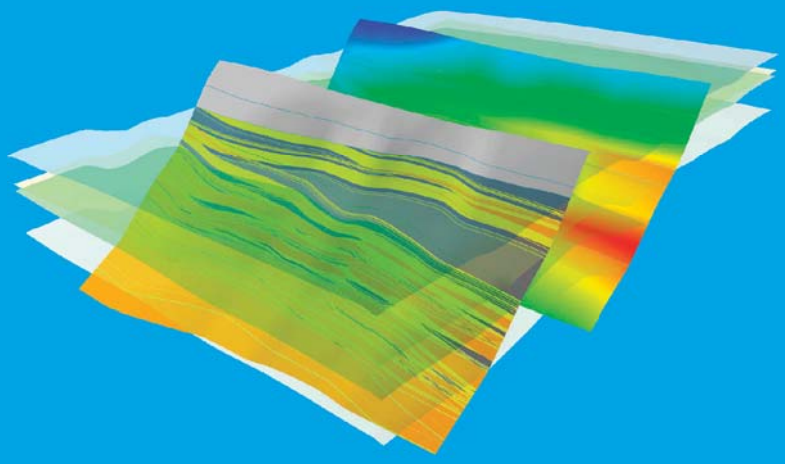
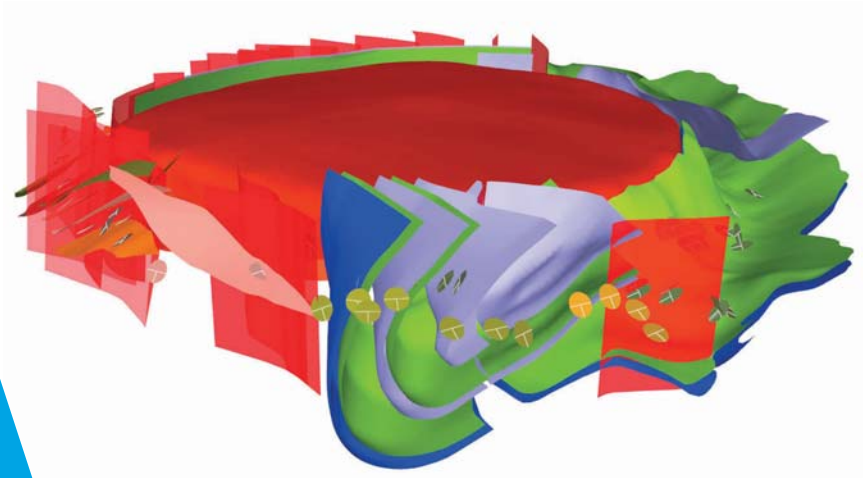
Boundary element modelling to simulate displacement on faults, and geomechanical analysis of surrounding fracture systems



New to 2D & 3D Kinematic Modelling



Improved 3D Model Building for Complex Surfaces

Build more accurate overturned horizon and fault meshes from points or interpretation data

Thermal Subsidence Modelling

More realistic sequential restorations of passive margins

Non-Planar Trishear

New algorithm implemented in 2D Move-on-Fault and the Construct Horizons from Fault

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